U.S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 110.

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE SPRING GRAIN-APHIS OR "GREEN BUG."

BY

F. M. WEBSTER,
*In Charge of Cereal and Forage Insect Investigations,*

AND

W. J. PHILLIPS,
*Entomological Assistant.*

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Miriam Welles Reeves, *collaborator.*

# LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
*Washington, D. C., December 28, 1911.*

SIR: I have the honor to transmit herewith for publication the manuscript of a bulletin on the spring grain-aphis, popularly known as the "green bug," by F. M. Webster and W. J. Phillips, of this bureau. The investigations upon which this bulletin are chiefly based began under a special appropriation made by Congress in the spring of 1907. These investigations have been continued without interruption up to and including 1911. Preliminary reports upon the work were published in Circulars Nos. 85 and 93. The present report, however, is a complete record of the entire investigation, including many aspects of the problem not before touched upon in any publication relating to this group of insects. I recommend the publication of this manuscript as Bulletin No 110 of the Bureau of Entomology.

Respectfully,

L. O. HOWARD,
*Entomologist and Chief of Bureau.*

HON. JAMES WILSON,
*Secretary of Agriculture.*

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# THE SPRING GRAIN-APHIS OR "GREEN BUG."

## INTRODUCTION.

Investigations of the spring grain-aphis, or "green bug" (*Toxoptera graminum* Rond.) (fig. 1), in America were first begun by the senior author in the year 1884, at Oxford, Ind., where the insect was accidentally introduced with, or had in some obscure way gained access to wheat plants which had been transplanted from the open to rearing cages standing out of doors on a blue-grass lawn (June 6) and used in carrying out investigations on the greater wheat straw-worm (*Isosoma grande* Riley). At that time the insect gave no indication of its present economic importance and for this reason was not then given special attention.

In 1890, when the pest really first gave evidence of its capabilities as a grain destroyer over a wide range of country, the senior author again took up its study, gaining considerable additional knowledge of its habits and of the influences of temperature and season upon its abundance. (See Diagrams I–V.)

The less serious outbreak of 1901 was not investigated and our information relative to it is derived chiefly from correspondence of the bureau for that year.

The incipient outbreak of 1903 was reported from Texas by Prof. E. D. Sanderson, at that time State entomologist, and from South Carolina by correspondents of the bureau.

The last and most disastrous outbreak of all, that of 1907, was investigated not only by both of the authors, but by Mr. C. N. Ainslie, who began his work on the species at Summers, Ark., on March 18, continuing the investigation almost uninterruptedly through the summer, working over the country from central Oklahoma northward to Canada, and returning to Washington in September. The junior author spent April, May, and a portion of June in Oklahoma and Kansas in field investigations, returning to Richmond, Ind., where he was at that time located and where he took up a systematic study of the insect, its habits, and development—a study which has been continued up to the time of preparation of this manuscript for publication. Messrs. E. O. G. Kelly and T. D. Urbahns spent much time in a study of the parasites; indeed, most of the assistants in cereal and forage insect investigations have

contributed more or less to our knowledge of the pest and its natural enemies, and throughout the following pages credit has been given

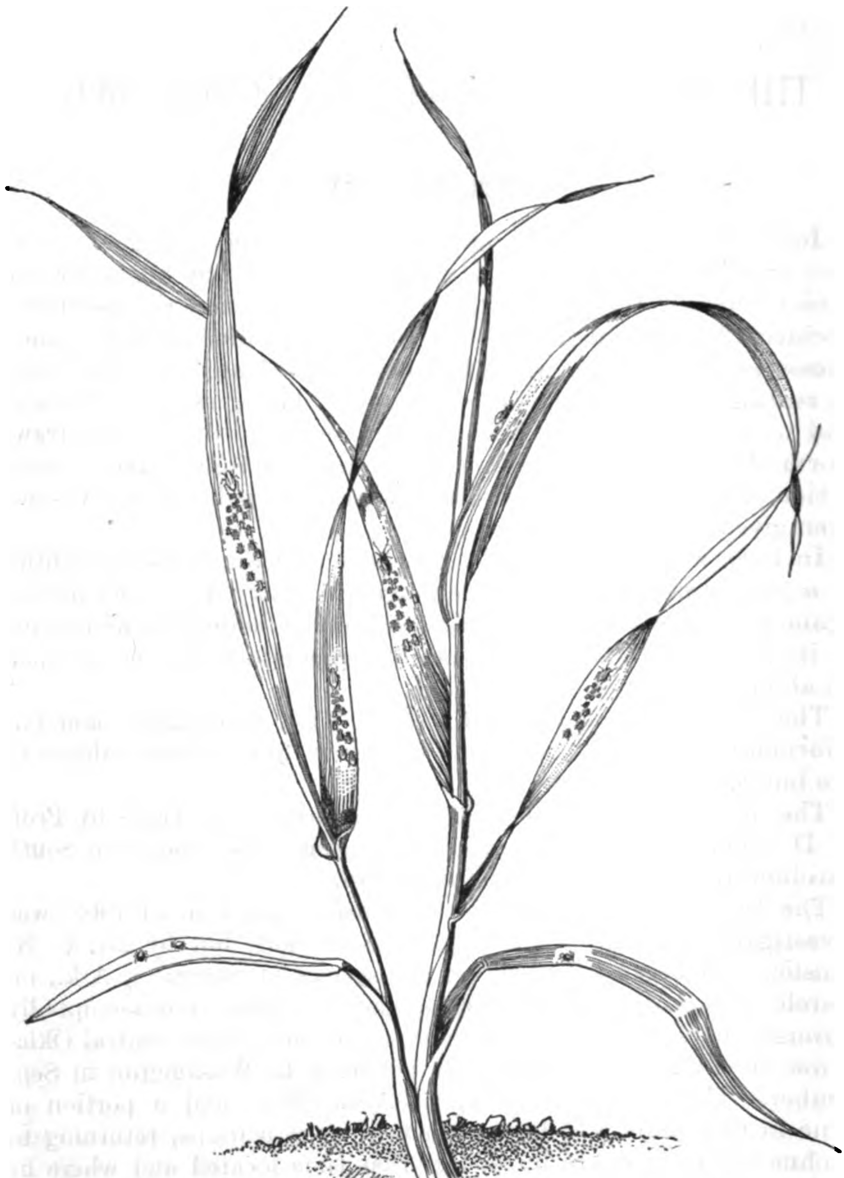

FIG. 1.—The spring grain aphis (*Toxoptera graminum*): Wheat plant showing winged and wingless viviparous females with their young clustered on the leaves, and a few parasitized individuals on lower leaves. About natural size. (Original.)

each individual where possible to do so. For a critical, technical study of the parasites of the species, credit should be given Mr. J. C. Crawford, assistant curator, Division of Insects, U. S. National

Museum, and Mr. H. L. Viereck, expert, Bureau of Entomology, who are specialists in the parasitic Hymenoptera.

During the winter of 1907–8 Congress provided the sum of $10,000 for carrying on these investigations; otherwise this work would have been impossible.

## EARLIEST OBSERVATIONS ON THE INSECT IN AMERICA.

The first examples of *Toxoptera graminum* to be found in America and identified as such were probably collected with the oats plants which they were destroying by Mr. H. S. Alexander, of Culpeper, Va., on June 15, 1882. A letter in the files of the Bureau of Entomology, written on the above date and addressed to Hon. George B. Loring, then Commissioner of Agriculture, stated that he, Mr. Alexander, was sending by that evening's mail specimens of an insect which had almost entirely destroyed the oats crop in his neighborhood. But he very evidently neglected to indicate on or within the package the name and address of the sender. Under date of June 17, 1882, the records of the old Division of Entomology show, however, that a package of oats or wheat plants—exactly which could not be determined by the person making the examination—were received on that date, badly infested by what was determined as *Toxoptera graminum*. As there was nothing on or within the package to indicate the source from which the material came, the locality has since remained in obscurity. Upon a recent examination of the old letter files, the communication of Mr. Alexander was found and a reply thereto by Dr. Riley, dated July 7, 1882, stating that the communication had been received from Mr. Alexander, but that the specimens referred to by him had not arrived. As the Division of Entomology did not have these specimens before them when Mr. Alexander's letter was received, or did not connect these specimens with his letter it was assumed that the species was the well known *Siphonophora avenæ* Fab., a name at that time applied to what is now called *Macrosiphum granaria* Buckt. Evidently the connection between the letter and package was never investigated, as the insects in the package proved to be Toxoptera. It is significant that of the eight communications received at the Department of Agriculture about that time, from various points in Virginia and including also one from Maryland, all relating to the wheat louse, this one from Mr. Alexander is the only one not shown to have been accompanied by specimens, and also it was the only communication in which reference was made to the destruction of oats, all of the other letters alluding to insects found infesting wheat or rye, which were probably *M. granaria* Buckt. Without a doubt, therefore, the letter of Mr. Alexander refers to the package received June 17, 1882, without

name or address of the sender. A correspondent of the "Country Gentleman," writing over the initials G. C., from Chrisman, Rockingham County, Va., about 50 miles west of Culpeper, under date of June 16, 1882, makes this statement:

Wheat looking well and promising, but there is a little green bug on it that may injure it. This same little green fellow is ruining the oats in this neighborhood, and has already destroyed them entirely in many localities.[1]

It is not at all surprising that Toxoptera and Macrosiphum should have been confused at that time, as the former species was yet unknown in the country and its presence could only be determined from winged individuals. In all of the succeeding outbreaks of Toxoptera it has been more or less difficult to separate the wingless individuals of these two species definitely from each other, even experts having been often at fault where there were only immature individuals upon which to base a separation. In this connection Mr. B. F. White, writing from Mebane, N. C., January 28, 1890, complaining of damage at that time to oats in his locality by Toxoptera, specimens of which accompanied his communication, stated that the same insect appeared in 1882, in May. So, then, it seems quite likely that, while the discovery was first made at Culpeper, Va., the insect occurred over a considerable area of country in Virginia, extending southward into northern North Carolina (see fig. 2; Diagram I, p. 15).

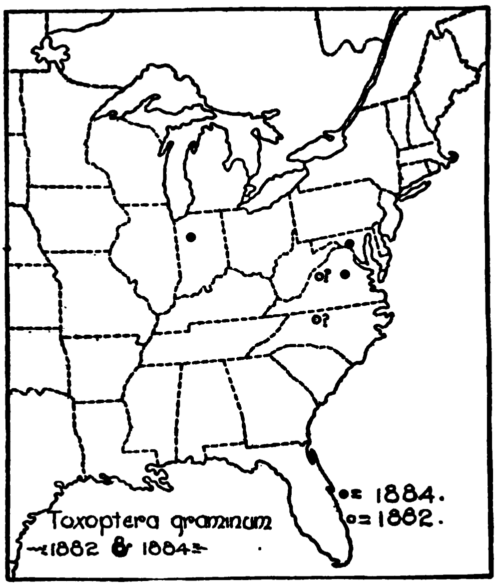


FIG. 2.—Map showing the locality from which the spring grain-aphis was received in 1882 and the two additional localities where it is probable that it also occurred in injurious numbers in that year; also the two localities where it was found in 1884. (Original.)

From the foregoing it would appear that at this early date there was a more or less destructive outbreak of this pest in the southern Atlantic States. That the species was confined to this area, however, is hardly possible, and indeed it is not beyond possibility that damage to oats may have extended much farther westward, though we have been unable to find definite proof to that effect. The all-important temperature influences are also indicated.

[1] Cultivator and Country Gentleman, vol. 47, p. 498, June 22, 1882.

On June 7, 1884, Mr. Albert Koebele found this species infesting wheat plants at Cabin John Bridge, situated in Maryland a few miles above Washington, and about July 1 of the same year the senior

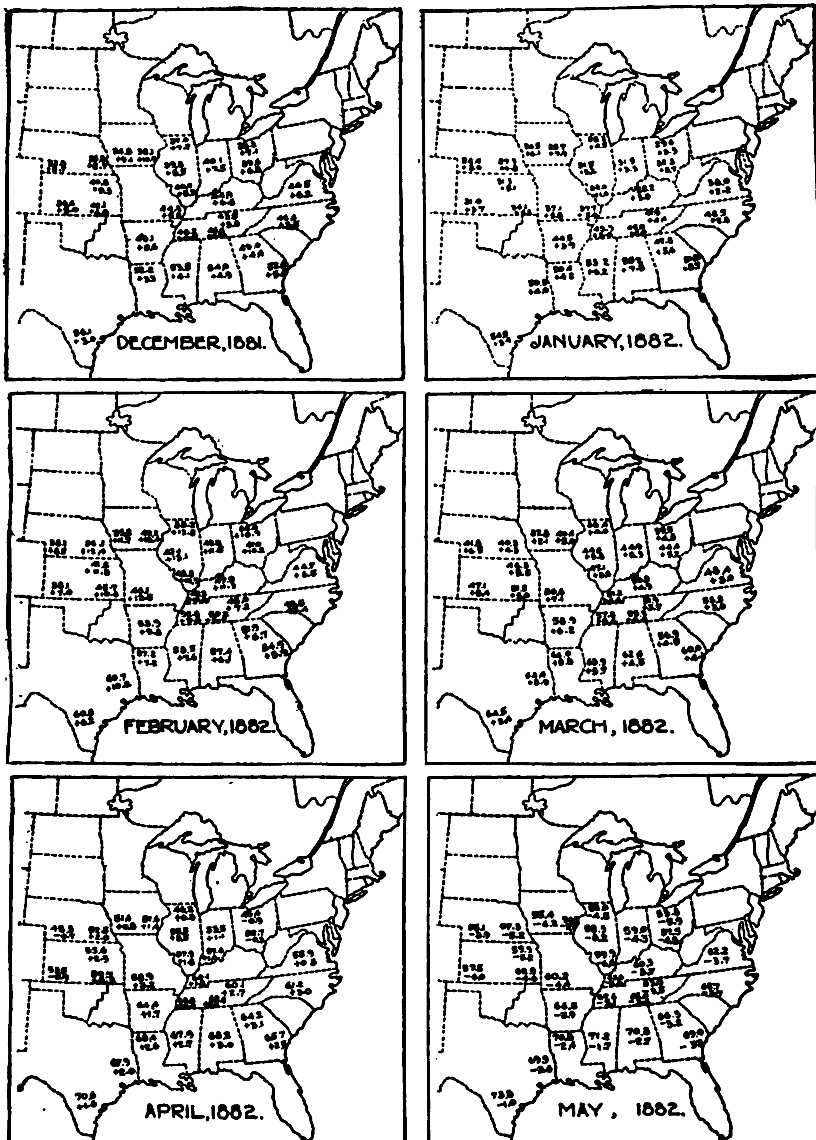


DIAGRAM I.—Maps of the United States east of the Rocky Mountains, showing normal temperature, upper line, and departure therefrom, lower line (+, above normal, and, —, below), for the critical period December, 1881, to May, 1882; above normal (+) in winter and below normal (—) in spring being favorable for outbreak of spring grain-aphis. (Original.)

author found it in one of his rearing cages, placed out of doors at Oxford, Ind. (see fig. 2). In the latter instance the species showed a preference for wheat plants over those of rye, and in September it

was common in the fields on volunteer wheat plants in the same locality and also about La Fayette, Ind. In some fields it was observed breeding on the young growing wheat throughout the autumn and early winter up to December 13. On the 30th of December it was still to be found alive in the fields, though not in great abundance.

## EARLY RECORDS IN EUROPE.

The first exact knowledge we have of this insect is its occurrence in excessive abundance about Parma, Italy, in 1847. Five years later, in 1852, Rondani, who described the species during this year, wrote to Prof. Bertoloni under date of June 14, also from Parma, relative to the insect as follows:

> We have in our city an innumerable number of insects of a species of the Aphis genus, of Linnæus, of the order of Hemiptera. Sometimes and in certain places the number of these insects flying in clouds in the air has been so great as to render them troublesome to people, entering the nose, eyes, and even the mouth, when one can not think how to protect oneself from them.

Elsewhere in this letter Rondani stated that he had never been able to find it on any but graminaceous plants, where it nestled on the leaves. In commenting on this letter of Rondani, Prof. Bertoloni took occasion to say that "innumerable specimens of the *Aphis graminum* Rondani are seen in the streets of the city of Bologna, and these have several times entered my nose and eyes when passing rapidly along the canal of Reno."

## KNOWN DISTRIBUTION IN THE EASTERN HEMISPHERE.

Besides these occurrences in Italy and Hungary (see fig. 3), in 1884 Dr. G. Horvath records an attack on oats in central Hungary, which took place in June, 1883, and 10 years later, in 1894, Prof. Carl Sajo records a second outbreak among growing oats, also in Hungary.

Schouteden, in 1906, records the species from Belgium, but gives no further data except that it affects the Graminaceæ.

Under date of October 7, 1907, Mr. H. Neethling, chief of the horticultural and biological division, department of agriculture, Bloemfontein, Orange River Colony, South Africa, in a letter addressed to the United States Department of Agriculture, stated that the wheat aphis was one of the greatest scourges with which the farmers of his colony had to contend, nearly the whole crop having been destroyed by it for several consecutive seasons. Again, under date of September 28, 1908, the same gentleman stated that the pest had been particularly active that season, it being estimated that more than 50 per cent of the entire wheat crop of the colony had been destroyed by its ravages. This latter communication was accompanied by specimens of *Toxoptera graminum* as well as a small

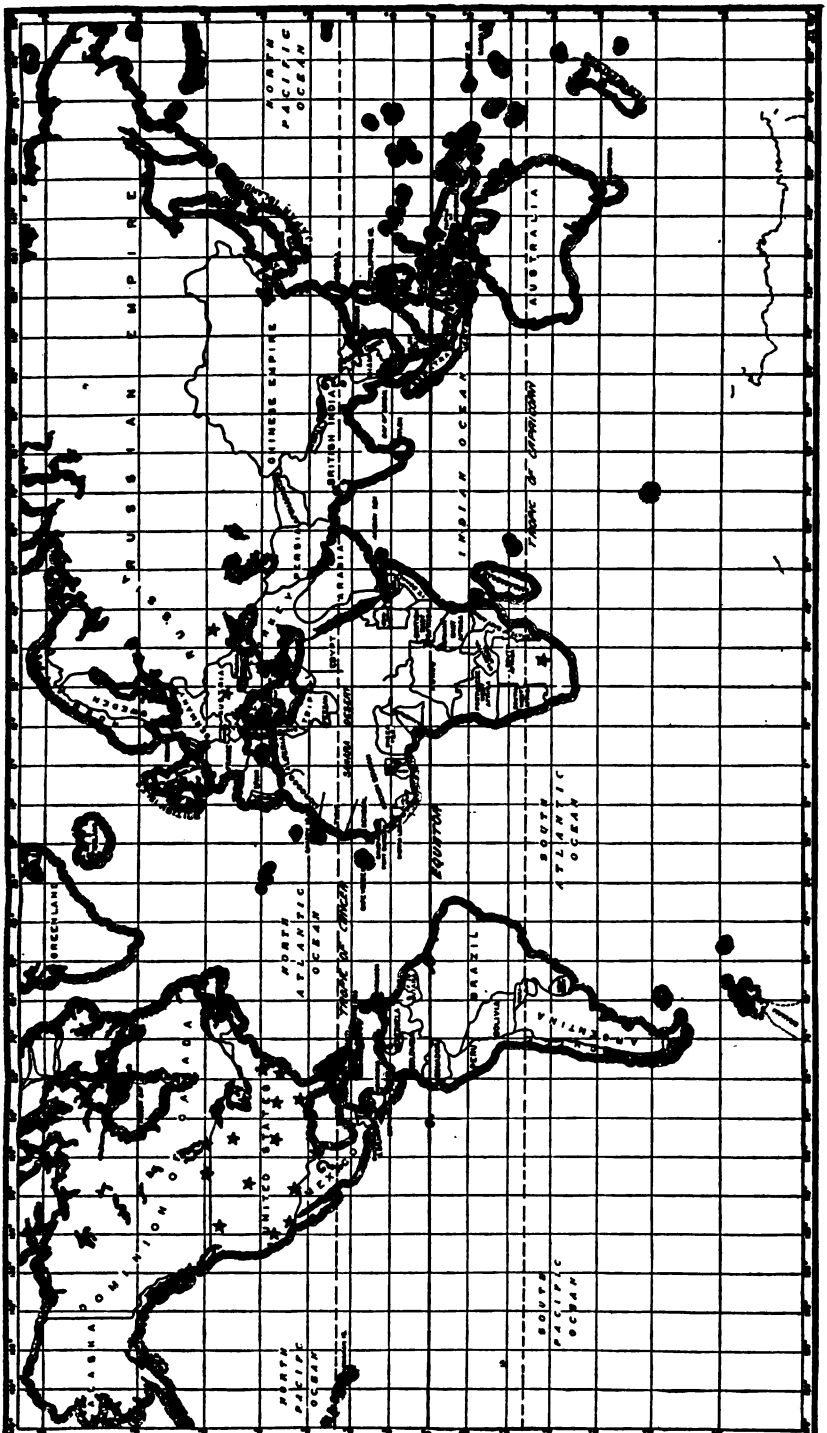


FIG. 2.—Map showing the distribution of the spring grain-aphis in both the eastern and the western hemispheres. Known localities are indicated by an *; suspected localities by ?. (Original.)

hymenopterous parasite, *Aphidius* sp., and larvæ and adults of a coccinellid, *Adalia flavomaculata* De G., both of which were observed destroying the aphidids. Under date of October 1, 1910, Mr. C. P. v. d. Merwl, assistant biologist of the same department, stated that another outbreak of the pest had taken place that spring and considerable damage had been done. In this communication the statement was made that the writer had personal knowledge of the occurrence of the species during the past 20 years, and that farmers had stated that they had always known of its occurrence in that country. It had, however, become seriously destructive during recent years and at that time farmers were being forced to give up growing wheat extensively on account of its ravages.

In the Agricultural Journal of India [1] Mr. H. Maxwell-Lefroy, government entomologist of British India, stated that the wheat aphis (*Toxoptera graminum*) seeks shelter in the depths of the grass roots; in different ways insects adapt themselves, but these had probably done it gradually, moving in from cooler to hotter areas step by step. From the illustration of this insect accompanying this statement and from specimens later submitted by Mr. Maxwell-Lefroy, it has been found impossible to determine the species involved as *Toxoptera graminum*.

On November 25, 1910, Mr. William Sewall, of Njoro, British East Africa, called at the office of this bureau to complain of the ravages of a green louse or fly which attacked and destroyed wheat on his farm in the above-named locality, situated almost directly on the equator in a prairie-like country at an elevation of 7,000 feet above sea level. A communication was received from Mr. Sewall bearing date of August 22, 1911, accompanied by specimens, in which he stated that the ravages now extend over an area of 700 acres. He also stated that his neighbor, Lord Delamere, who had not been troubled previously, experienced severe losses over an area of about 4,000 acres. The specimens accompanying Mr. Sewall's letter have been determined as *Toxoptera graminum* by Mr. J. T. Monell.

With these records of the known and probable distribution of *Toxoptera graminum*, it does not seem improbable that if the minute insects of the family Aphididæ were carefully studied this species would be found generally diffused throughout the temperate and tropical regions of the world.

## KNOWN DISTRIBUTION IN THE WESTERN HEMISPHERE.

With reference to the distribution of this insect in the Western Hemisphere (see fig. 4), it can be said that it has only been studied in the United States. Its occurrence in western Canada is well established. On the south it is known along the Mexican border from the Gulf of

[1] "Imported insect pests." Agricultural Journal of India, vol. 3, part 3, pp. 243-244, July, 1908.

Mexico almost to the Pacific Ocean. It has not actually been found in Mexico and no one has searched for it there. Wheat in Mexico is said to have been injured by a "green louse," and it is reasonable to suppose that the insect may occur far to the southward of its present known range of distribution. Its entire absence from eastern Canada and northeastern United States, except in eastern Massachusetts near Boston, where it seems to have been found by Mr. Paul Hayhurst in September, 1908, will be noted.

## THE OUTBREAK OF 1890.

(Fig. 5, p. 20; Diagram II, p. 21.)

Up to the year 1890 in this country the very destructive nature of this insect had not yet become apparent; hence it had not received the close attention that, as we now understand, it justly deserves.

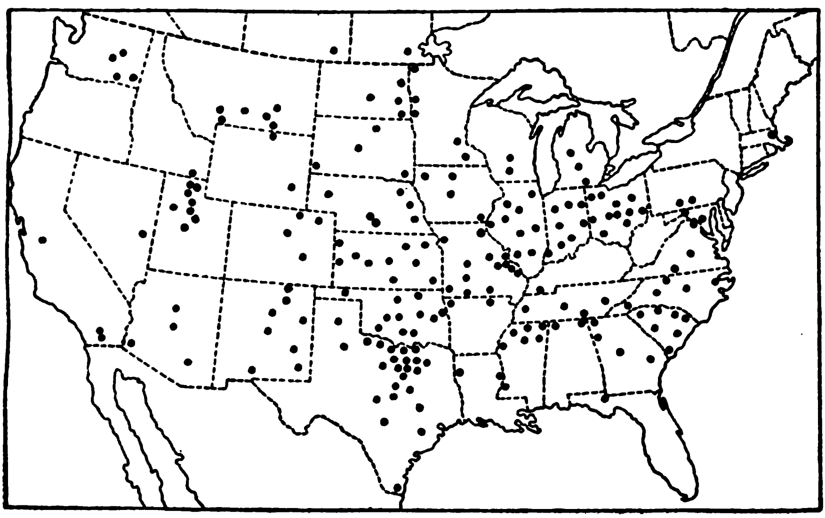

FIG. 4.—Map showing the known distribution of the spring grain-aphis in the United States and Canada. (Original.)

While the senior author was and had been engaged in grain-insect investigations in Indiana during the six years following its discovery by him at Oxford, the species was not looked upon as one of those deserving especial attention; therefore from 1884 to 1889 no notes were made upon it, and no references to it are to be found in the correspondence of the Division of Entomology. Mr. J. T. Monell, now of this bureau, however, has specimens in his collection from Illinois, taken in 1886.

During November and December, 1889, the insect was again observed in such abundance in fields of young wheat about Lafayette, Ind., as to attract the attention of the senior author, who found it repeatedly on young wheat in the fields during the entire winter. The influences of mild or high temperatures during winter, especially

in the South, and low temperatures during spring months were carefully observed and set forth in a report published later.[1]

As early as the middle of January, 1890, it was reported by Mr. P. C. Newkirk as killing the young wheat about Jalapa, Tenn., and on the 26th of the same month Mr. B. F. White, of Mebane, N. C., reported it as ruining both wheat and oats in his neighborhood. Mr. J. L. Fooks, writing on the same date from Era, Tex., stated that the insect had played sad havoc with the wheat in his neighborhood, while April 7 Mr. D. J. Eddleman, Denton, Tex., complained of the pest destroying the wheat. Writing in 1901 Mr. H. K. Jones, Valley View, Tex., stated that the insect appeared there about 10 years pre-

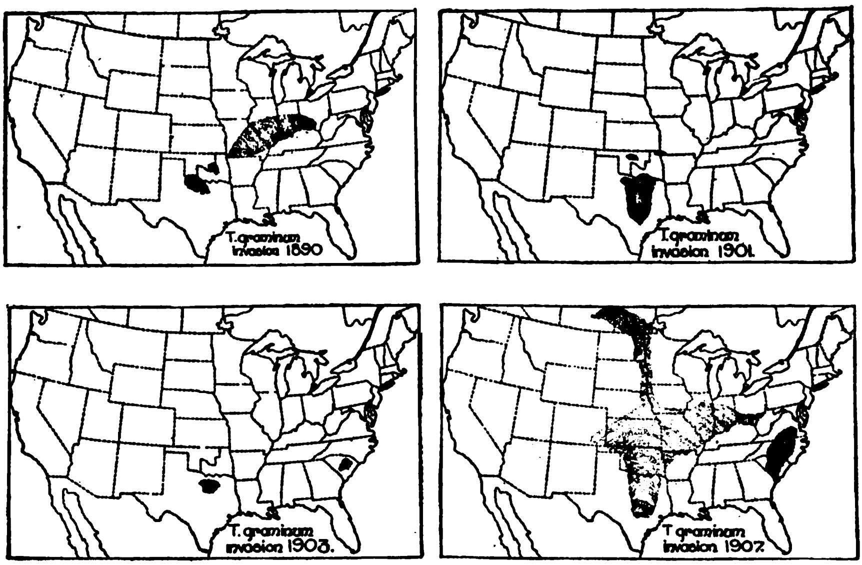


FIG. 5.—Maps showing areas covered by outbreaks of the spring grain-aphis during the years 1890, 1901, 1903, and 1907. (Original.)

vious and killed about all the wheat in the county. From this and other correspondence, accompanied by specimens, it seems that wheat in Cooke, Grayson, Collins, Denton, and Wilbarger counties, Tex., was more or less damaged by this pest.[2] No reports are at hand showing injuries to wheat or oats in what was at that time Oklahoma and Indian Territories, for the reason that little of either of these grains was at that time grown. But we now know that grains were not essential to its presence in that country.

In Missouri the situation was more acute and strongly indicates that the pest was present in southeastern Kansas and northern Arkansas. According to Mr. Monell's notes, the pest completely

[1] Insect Life, vol. 4, pp. 245-248, 1892; Bul. 22, Div. Ent., U. S. Dept. Agr., pp. 64-70, 1890; Yearbook U. S. Dept. Agr. for 1907, pp. 239-241.

[2] Insect Life, vol. 3, p. 75.

destroyed a field of 60 acres of oats belonging to Hon. Roland Hazard at Mine Le Motte, situated about 100 miles south of St. Louis, Mo.,

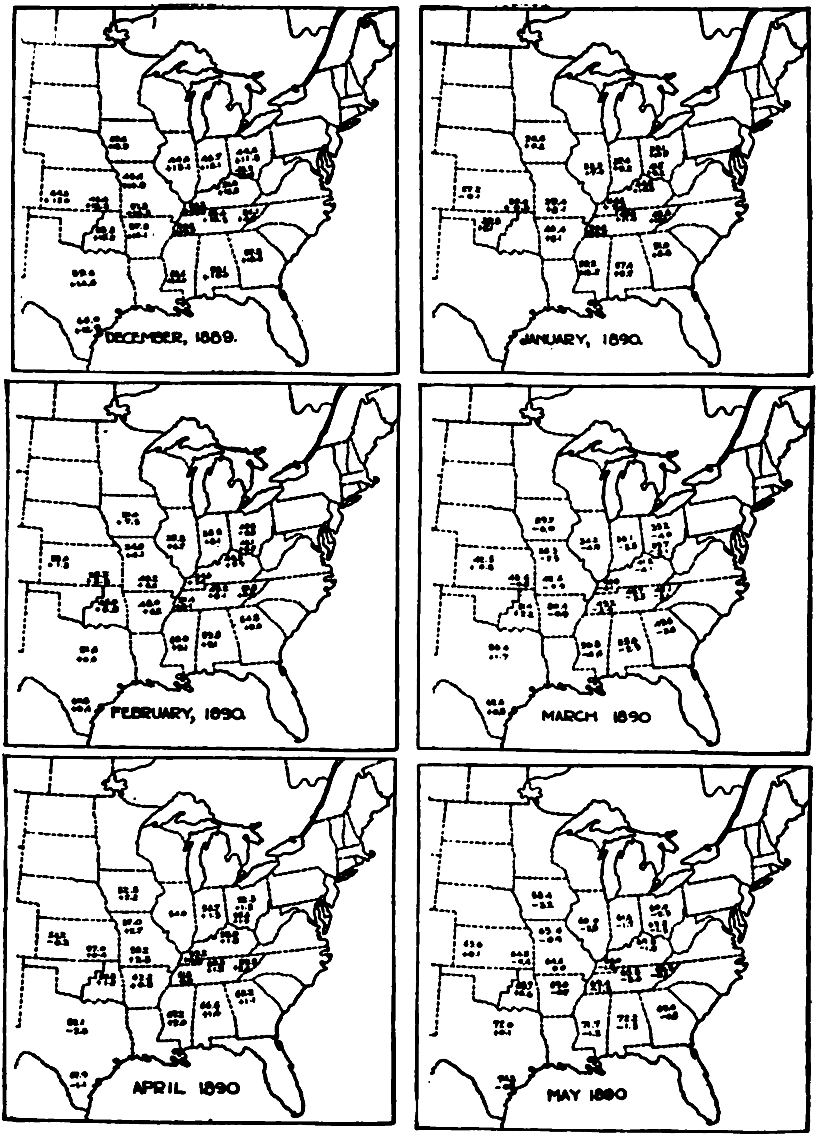


DIAGRAM II.—Maps of the United States east of the Rocky Mountains, showing normal temperature, upper line, and departure therefrom, lower line (+, above normal, and −, below normal), for the critical period December, 1889, to May, 1890; above normal (+) in winter and below normal (−) in spring being favorable for outbreak of spring grain-aphis. (Original.)

the observations being made June 10, 1890. In Missouri the situation appears to have been pretty clearly set forth by Colman's Rural World, then the leading agricultural paper of the Southwest. In the

issue of that publication for June 12, 1890, the following statement is made:

The oat crop in the vicinity of St. Louis and probably extending a hundred miles in every direction is being completely destroyed this season by an aphis, commonly called, we believe, the Texas louse. The oat fields look brown and bare, this little green insect sucking the juices and sapping the vitality of the plant. It increases with amazing rapidity, fully as rapidly, we judge, as the hop louse, swarming in every direction and carrying destruction in its path. The only thing they seem to feed upon is the oat.

In the issue of the same publication for June 19, a week later, the following statement is made:

The oat crop this season will be almost a total failure in St. Louis County. Hundreds of acres have been totally destroyed by the aphis, or plant louse, the depredations of which have been so widespread and effective that only a very small per cent of the crop will mature. Hundreds of farmers have despaired of the crop entirely, and have plowed up their oat fields and planted corn instead.

The Weather Crop Bulletin of the Missouri State Board of Agriculture for the week ending July 4, 1890, gives the following estimates of the oats crop throughout the State. Northeastern Missouri, 63 per cent; northwestern Missouri, 70 per cent; southeastern Missouri, 25 per cent; central Missouri, 30 per cent; southwestern Missouri, 54 per cent. As another writer describes it, the damage was most serious south of a line drawn diagonally across the State from the northeast to the southwest corner.

The statement made in Colman's Rural World to the effect that the oats crop within a radius of a hundred miles of St. Louis had been completely destroyed by the oats aphis or "Texas louse" would include within this radius territory nearly half way across southern Illinois. Mr. B. F. Johnson, of Champaign, Ill., an agricultural writer, who appears to have traveled over the country quite extensively and observed the situation closely, writing to the Country Gentleman under date of June 24, sized up the situation as follows:

For some weeks after it was seen above ground, the oat crop looked well and promised well, and this continued to the first or about that date in June. Since then oats have been going behind hand, with the threat now over them that all the crop has been more or less seriously reduced in yield and a considerable portion will be lost. In fact, the oat aphis, after ruining the oat crop south, has appeared on the black soil in force and nothing less than many and heavy rains will arrest his progress. As before reported, the dry weather in May favored a light growth of straw, as in 1887, and hopes were entertained that long heads of sound grain would result. Such would have been the case had not the aphis appeared and sucked a part of the life-blood of the plants. The present appearance of a majority of oat fields—the acreage on the black soil counties is an enormous one—is rather uneven as to growth, color, and measure of development, a part of which is owing to the greater or less fertility of the soil, but chiefly to the depredations of the aphis, that takes the weakest plants growing on the thinnest land.

In the issue of August 14 of the same publication, Mr. John M. Stahl, of Adams County, Ill., states that in western Illinois the only

cause of the failure of the oats crop recognized was the green louse. Directly upon this point his statements were as follows:

We never had a better prospect for oats until the green louse began its work. Some fields were not attacked by the louse, though it infested surrounding fields. From the fields not attacked by it there was a splendid yield of oats; while, of course, the other fields yield scarcely anything. In every township there were a few fields that were not attacked by the green louse and that made a good yield. The fact that those fields not attacked by the green louse invariably made a good yield, while those that were attacked made a poor yield, is proof that in this part of the State, at least, the green louse was the prime cause of the failure.

This feature of the apparent immunity of some fields from attack while others adjacent were destroyed has since been observed again and again, especially along the borders of a serious invasion, which was precisely the stuation in western Illinois at the time indicated by Mr. Stahl. In Indiana the senior author investigated the outbreak personally, and while the pest was present as far north as Lafayette, there was little if any damage from its attacks north of Indianapolis. In the neighborhood of Franklin on June 25 many fields were badly damaged, but the injury was much more severe to the southward and at New Harmony, Ind., on June 11, the oats crop was ruined. The same was to be said of the country across the Wabash River in Illinois. While both Toxoptera and Siphonophora were present in most cases the former largely outnumbered the latter and there was no difficulty in properly crediting the destruction to Toxoptera.

The occurrence of this insect in southern Ohio was greatly obscured owing to the fact that it was, as elsewhere, confused with *Macrosiphum granaria* Buct. Clarence M. Weed, writing for the Ohio Farmer (see issue of July 12, 1890), states that in Ohio the grain plant louse had been reported from Pickaway, Clermont, Butler, and Franklin counties. It seems, however, that in Clermont County, according to Mr. Ed. C. Ely, the plant lice were at work as early as May 30.

In a later issue of the same paper, July 19, 1890, Hon. Abner L. Frazer, of Clermont County, Ohio, stated that the aphidids were very numerous in his fields on June 9. While it is impossible to say with absolute certainty that all damage was due to Toxoptera, nevertheless Waldo F. Brown, writing from Butler County[1] on June 19, says:

Oats are in a critical condition. The leaves have turned red. It has not the appearance of rust, looking more like the firing of a plant in dry weather, and I should not wonder if the crop proved a total failure.

In both Illinois and Missouri the aphidid causing the damage was termed the "Texas louse," and wherever a technical name for it was used at all it was called *Siphonophora avenæ* Fabr. Because Toxoptera was at that time but little known, and owing to the

[1] Country Gentleman, June 26, 1890, p. 506.

extreme difficulty in separating its young and its wingless adults from those of other species, it would seem that more or less damage to the oats crop might be with justice accredited to Toxoptera in Butler, Miami, and Clermont counties in extreme southern Ohio.

## THE OUTBREAK OF 1901.

(Fig. 5, p. 20; Diagram III, p. 25.)

The outbreak of 1901 was less extensive than that of 1890. Little damage was reported south of Waco, Tex., but from this point northward wheat was more or less injured, and oats were destroyed to the northward into what was at that time Oklahoma and Indian Territories. The farthest point to northeast at which damage was reported, with specimens of the depredator, was Saratoga, in extreme southwestern Missouri. The specimens accompanying correspondence from Texas and Oklahoma gave ample proof of the identity of the destroyer, which in Texas alone ruined grain to the extent of several million dollars. In central Texas the ravages of the pest began to attract attention early in March, while the report from Missouri came under date of April 30. It will be noticed that the direction taken by this invasion followed very closely that of 1890 (see fig. 5), beginning, however, farther south in Texas, not extending so far to the northeast, and dying out, as it were, earlier in the season. These phenomena will be explained farther on under meteorological influences.

## THE OUTBREAK OF 1903.

(Fig. 5, p. 20; Diagram IV, p. 26.)

As foreshadowing the impending outbreak of 1903, as early as November 26, 1902, Mr. J. F. Ordman, writing from Windthorst, Tex., complained to this bureau of the ravages of the green louse, stating that it had destroyed several small areas in his wheat field and that it was reported generally prevalent in his neighborhood. This outbreak was, however, an incipient one and resulted in little injury, the seriously infested areas being confined to northern Texas, exclusive of the "Panhandle," with possibly the country in the then Oklahoma and Indian Territories bordering the Red River, and in South Carolina. While the outbreak was thus limited in area, the natural enemies of the pest in the West evidently fell far short of completely subjugating it. In March, 1904, Prof. E. D. Sanderson and Mr. E. C. Sanborn found it in Grayson County, Tex., sufficiently abundant to work serious injury in the fields of young wheat and oats, in some cases the destruction of the growing grain

being complete. The same gentlemen reported the pest present in limited numbers during the spring of 1904 in Collin, Hunt, and

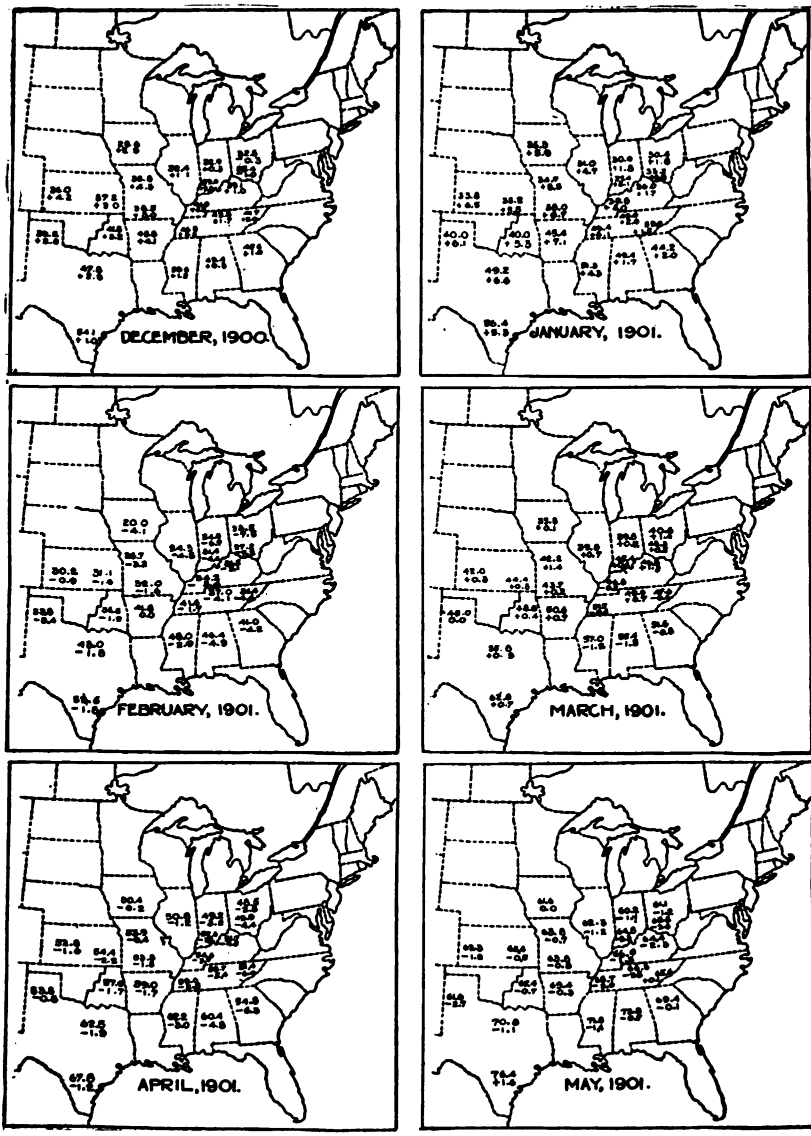


DIAGRAM III.—Map of the United States east of the Rocky Mountains, showing normal temperature, upper line, and departure therefrom, lower line (+, above normal, and −, below), for the critical period December, 1900, to May, 1901; above normal (+) in winter and below normal (−) in spring being favorable for outbreak of spring grain-aphis. (Original.)

Travis counties. This year, however, the parasites evidently did more effective service, as at Whitewright, Grayson County, Tex., on March 10, 1904, Mr. Sanborn found that 60 per cent of the Toxoptera

in some oats fields were parasitized. The junior author spent some time in northern Texas during November and December, 1904,

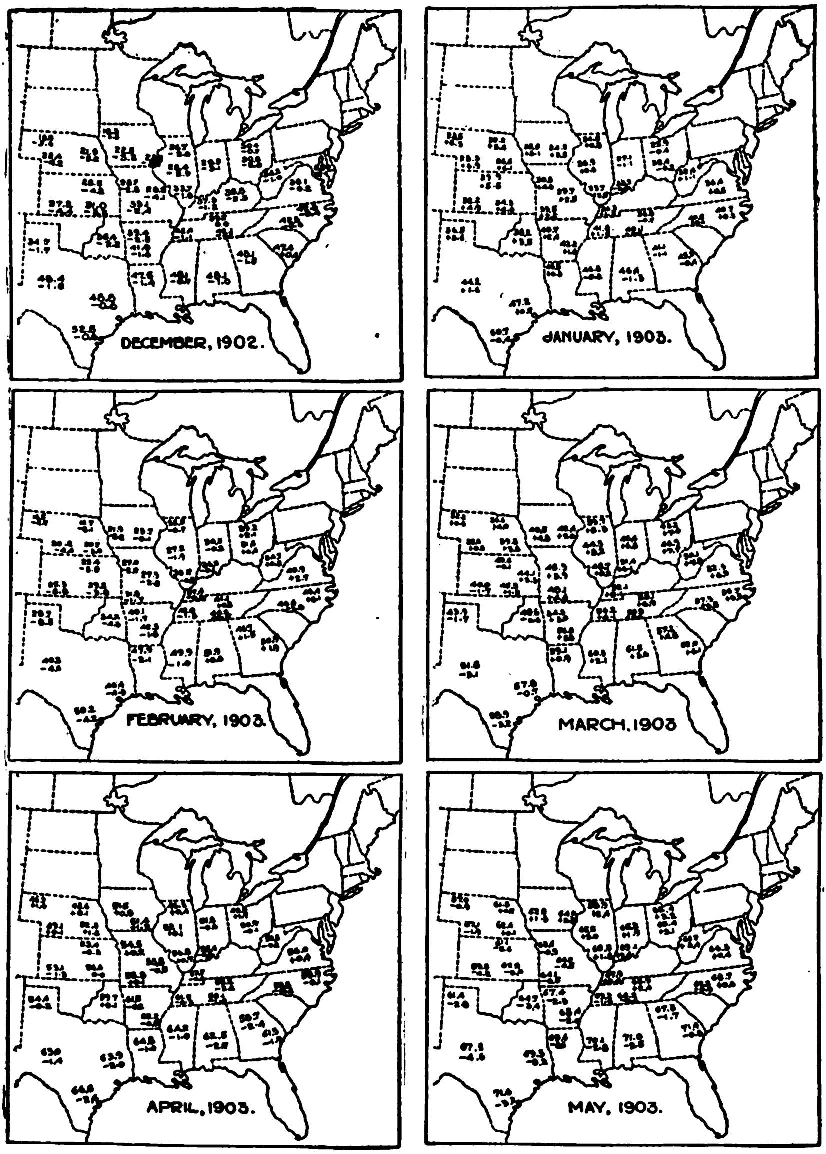


DIAGRAM IV.—Map of the United States east of the Rocky Mountains, showing normal temperature, upper line, and departure therefrom, lower line (+, above normal, and –, below), for the critical period December, 1902, to May, 1903; above normal (+) in winter and below normal (–) in spring being favorable for outbreak of spring grain-aphis. (Original.)

investigating insects in the fields of wheat and oats without finding the pest. He was not looking for this species particularly, and it was doubtless still present in very limited numbers.

## THE OUTBREAK OF 1907.

(Fig. 5, p. 20; Diagram V, p. 28.)

The outbreak of 1907 was by far the most serious and widespread that has occurred in the United States up to the present time. Starting in east-central Texas, the invasion swept northward and eastward, covering a somewhat fan-shaped area, through Oklahoma, Kansas, northwestern Arkansas, Missouri, and across Illinois to within 60 miles of Chicago. Though possibly not doing so much damage in the Ohio Valley as in 1890, it extended westward through Oklahoma and Kansas into southeastern Colorado. While not especially injurious to oats and not at all to wheat in the States of Nebraska, Iowa, Minnesota or the Dakotas, the late Dr. James Fletcher states that in Canada it actually did some damage in Saskatchewan. Less damage was probably done in Indiana and Ohio than in 1890, though the ravaged area in general followed the ground covered by the previous outbreaks; in this latter case the northeastern terminus of the seriously ravaged area appeared to be confined more closely to the upper Mississippi River and Illinois River valleys than to that of the Ohio River, thus sweeping more broadly to the northward. On the Atlantic coast fall oats were destroyed or badly injured in South Carolina, and both wheat and oats in western North Carolina. In Virginia, Kentucky, and Tennessee neither grain was, as a rule, seriously damaged. The areas shown in figure 5 indicate all injury, even though slight, in occasional and widely separated fields. In the valleys of the upper Missouri River and the Red River of the North there was little or no injury, and it seems doubtful if the pest occurred in that section prior to this outbreak.

Forebodings of trouble from this pest came as early as November and December, 1906. According to copies of Mr. Sanborn's notes, as placed at our disposal by Prof. A. F. Conradi, the species was sent to the Texas experiment station from Howe, Grayson County, Tex., where it occurred on oats, as early as November 14, 1906, and one day earlier from Allen, Collin County, of the same State, where it was present in great numbers attacking volunteer oats plants. On December 22, 1906, it was sufficiently abundant about Plano, Collin County, Tex., to destroy oats in patches in the fields, its natural enemies at the time being in a dormant condition because the temperature had not reached and remained at a degree that would render them active. During January and February, 1907, these conditions continued, the Toxoptera breeding and spreading unrestrained by its enemies, so that the area over which it was becoming destructive continually increased.

Rumors of injuries by this pest came to us early in January, 1907, from east-central Texas, where the "green bugs" were reported to Mr. W. D. Hunter, in charge of cotton boll weevil investigations of

this bureau, as attacking fall oats. During this month in Texas east of a line drawn from near Gainesville through Abilene and San

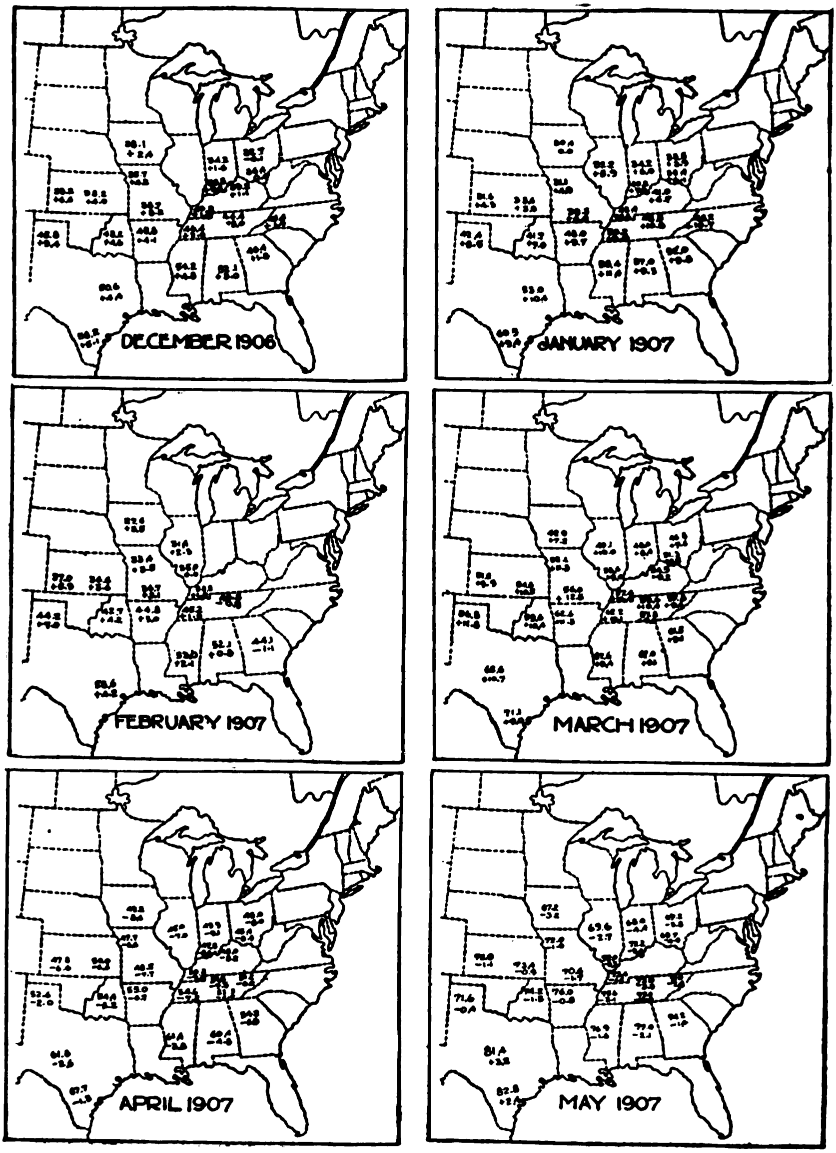


DIAGRAM V.—Map of the United States east of the Rocky Mountains, showing normal temperature, upper line, and departure therefrom, lower line (+, above normal, and −, below), for the critical period December, 1906, to May, 1907; above normal (+) in winter and below normal (−) in spring being favorable for outbreak of spring grain-aphis. (Original.)

Antonio to Galveston the temperature was 9° F., above the normal. Within this area was a smaller one, the boundaries of which may be indicated by a line drawn from Texarkana to Fort Worth, Waco, and

Joaquin. Over this latter area the temperature for the same month was 12° F. above the normal, and within this latter area the pest first began its work of destruction.

For reasons to be explained later in their proper place, the spread of the pest was much more rapid to the north and northeast from north-central Texas than it was in the opposite direction. In March the pest was found generally present about San Antonio, Kerrville, Menardville, and New Braunfels, of that State, but because of the small acreage of grain grown in that section the damage was not serious. Indeed, the same may be said of the country west of a line drawn from western Wilbarger County to the Brazos River at Round Timber, Baylor County, and west of the Brazos to and except about Waco. East and north of this the damage ranged from serious to total ruin.

As early as March 6 it was also reported to the bureau as destroying wheat in the vicinity of Summers, northwestern Arkansas. This was probably due to local causes, uninfluenced by invasions of swarms of winged viviparous females that were being continually swept from off the more disastrously affected country to the southwest and drifting toward the northeast. Mr. C. N. Ainslie was instructed to proceed from Washington, D. C., to this part of the country, where he arrived on March 16. On March 15 the Texas Grain Dealers' Association, through its secretary, Mr. H. B. Dorsey, made an appeal to the chief of this bureau for aid in devising means for destroying the pest and curtailing or preventing its ravages. In response to this appeal the junior author was dispatched to Fort Worth, Tex., arriving there on March 26. The situation here was found to be most serious. Hundreds of acres of both wheat and oats had been wiped out of existence; in many cases fields were observed where it was impossible to find a living plant, and as a rule numbers of such fields were being plowed and prepared for other crops. Plate I, figure 1, shows a field entirely destroyed. The weather at this time was hot and dry and Toxoptera appeared to have been entirely overcome by its natural enemies.

On March 25, 1907, a telegram was received from the Roosevelt Grain Elevator Co., of Hobart, Okla., reporting serious attacks from Toxoptera and appealing to the Secretary of Agriculture for assistance. The junior author was at once instructed to proceed to Hobart, where he arrived April 1, remaining until April 5. This point appeared to be on the western border of serious injuries by the pest, and the situation was therefore not so grave as in Texas. From the junior author's observations it appeared that much of the damage that was being done was caused by insects which had drifted into the fields and not from individuals originating therein. This was evidenced by the fact that in wheat fields where a part had been sown

early and the remainder later in the season the latest sown was very much more seriously damaged than that sown earlier. About the only portions of the early-sown part of the field to suffer serious injury were on the poorest soil. In short, the Toxoptera was found to be working its greatest damage in late sown or pastured wheat fields and among the young oats. Natural enemies were busily at work and apparently fast overcoming the pest.

In the meantime Mr. Ainslie had found the pest destroying wheat in spots in the wheat fields about Fayetteville and Summers, Ark., March 16 to 20, as well as at Chandler, Okla., March 24, and at Guthrie, Okla., on March 25. Near the latter place large circles were observed in the otherwise green fields of wheat. In the center of these circles the red soil was exposed by reason of the killing of the wheat plants, and these exposed circular areas were bordered by a band or girdle of yellow half-dead wheat plants, where the Toxoptera were most abundant. (See Pl. I, fig. 2.) In another field in this vicinity there was a stack of oats straw of the previous year, and from this stack a dead area extended at least 100 feet to the south. This area was nearly circular, with the stack almost in the center of the circumference. Near and surrounding the stack was an area of dead volunteer oats, and beyond this a stretch of bare ground indicated where wheat had once stood. From people occupying a house near by something was learned of the previous history of this straw stack from which Mr. Ainslie determined that volunteer oats had sprung up after thrashing in 1906; these oats turned brown soon after, causing some wonder among farmers, and during the winter the plants died. The trouble spread to the wheat adjoining and here the wheat plants died early in the spring. There was here seemingly a repetition of the conditions in the fields about Summers, Ark., where Toxoptera infesting volunteer oats extended its destruction from these to the wheat near by.

On March 26, between Guthrie and Kingfisher, Okla., Mr. Ainslie observed that the dead spots in the wheat fields were a striking feature of the landscape, for in the sunshine the bright green of the young grain made a striking contrast with the yellow-rimmed red circles where the Toxoptera had destroyed the wheat. Occasionally a field was free from these areas, but more of them were frightfully spotted in this manner. A field of wheat that was pastured more closely than most grain fields lay in the edge of Kingfisher and showed the attack of the Toxoptera worse than in adjoining grain. On March 27, at Kingfisher, Toxoptera was flying by the millions, the air being full of the migrants, and farmers who drove to town were covered on the windward side to their annoyance. The aphides seemed for the most part to fly low, but the wind hurried them at such a rapid rate that they might easily have been invisible when higher in the air. On the

following day large numbers of Toxoptera were on the wing, always moving north. In a field of oats, sown in February, the plants had hitherto been very thrifty, but at this time in a great many of the drill rows the plants were about dead for a space of 8 or 10 feet, and in case of later sown fields the plants were all fast dying under the attack. There was becoming gradually apparent a fact of considerable importance regarding the relative number of winged forms in the fields. In oats fields where the food was succulent and good it was difficult to find a single pupa, while in older and less succulent wheat, perhaps within a yard of the oats, pupæ would form 75 or 80 per cent of the population of the blades. This was afterwards verified repeatedly by observation and by actual counting; indeed, throughout the entire spring this fact seemed to be substantiated.

From March 31 to April 3 Mr. Ainslie carefully examined fields of wheat and oats in the vicinity of Wellington, Kans. He found wheat fields invariably evenly infested with Toxoptera though nowhere in any great numbers. Many of these were winged adults, indicating that they were migrants, and the young about them clearly evidenced a recent invasion. No dead areas were observed in the fields north of Pond Creek, Okla., but between Kingfisher and this point the circular dead spots were plainly in evidence. These dead areas, (Pl. I, fig. 2), from their regularity in the field, plainly indicated the rows of oats shocks of the fall previous and were clearly to be seen where the oats had been shocked and allowed to stand through a period of wet weather. This generally produced a vigorous growth of volunteer oats when the shocks were finally stacked or removed, and in this young grain the Toxoptera seem to have had an early start. In some cases it was easily possible to observe these spots all over a field, although the volunteer oats were rarely entirely killed—perhaps only changed to a reddish color. The infestation seemed to be more marked in the wheat in the vicinity of these spots, and later the Toxoptera swarmed about these places.

It may be noted that these observations of Mr. Ainslie in northwestern Arkansas, southern Kansas, and northern Oklahoma were made upon the same dates as those of the junior author about Fort Worth, Tex., and at Hobart in southern Oklahoma, thus covering a latitude of nearly 400 miles.

Mr. Ainslie returned to Kingfisher, Okla., April 3, and was joined there by the junior author on the 8th of the same month, where a number of experiments were carried out in the field, the results of which are given in the proper place. By the 8th of the month parasitized Toxoptera was found excessively abundant in the fields, in evidence of which a case was noted where a section of a leaf of wheat 1½ inches in length carried 43 brown, parasitized individuals. Mr. Ainslie left Kingfisher, Okla., for Wellington, Kans., on the following

day, taking with him more than a bushel of these wheat plants with the parasitized Toxoptera thereon and on the 11th this material was put out in a field near Wellington where the Toxoptera was the most plentiful, in order to determine if it was possible to increase the limited numbers of parasites at the time observable in the field, so as to expedite the work of the latter in overcoming the pest. This was the first artificial introduction of Aphidius into Kansas, six days after which Prof. S. J. Hunter began distributing parasites. The following day a second lot of material sent from Kingfisher by the junior author, some of it carrying as many as 100 parasitized Toxoptera to a single blade of wheat, was distributed in a wheat field, also near Wellington, by Mr. Ainslie, some of it being placed in bunches to protect it from the weather and the remainder scattered over the ground among the growing wheat. The Aphidius already observed in the fields on the 11th appeared to be on the increase, as many as 11 parasitized individuals being observed on a single growing leaf, though but few of the adult parasites were observed abroad in the fields. On April 18 parasites were sent to McPherson and on May 18 to Manhattan, Aphidius being present in the fields at the time of introduction. These introductions will be taken up in detail farther on in this bulletin.

On April 12 a letter was received from Mr. J. A. Akers, at Hooker, Beaver County, Okla., stating that the "green bug" was destroying his wheat. The junior author, being notified of the outbreak, proceeded there, arriving on April 24, and found that Mr. Akers's field was the only one in that locality that had been injured, and, in fact, it was outside the zone of destructive infestation in this State. This field comprised 52 acres, over a portion of which oats had been sown the previous year, while cowpeas had been grown upon another and much smaller part. Volunteer oats were plentiful over the first mentioned area. One of the infested spots was located among the wheat and volunteer oats, while the second spot was in the area previously devoted to cowpeas. There were no other injured spots in the whole field, although an occasional Toxoptera could be found here and there over the field, which was also true of other fields in this vicinity. It is a significant fact that young plants of *Agropyron occidentale* Scrib. were found growing in both of these spots and they were as badly infested as the wheat plants. A few parasitized Toxoptera were found, but the parasites were apparently developing slowly on account of cold weather.

The junior author went to Indiana the latter part of the first week in May, but was recalled to Kansas and reached Manhattan on the 18th, where he was met by the senior author, and a final experiment for the artificial introduction of parasites was here planned and begun at this time, the results of which are given farther on in the proper place.

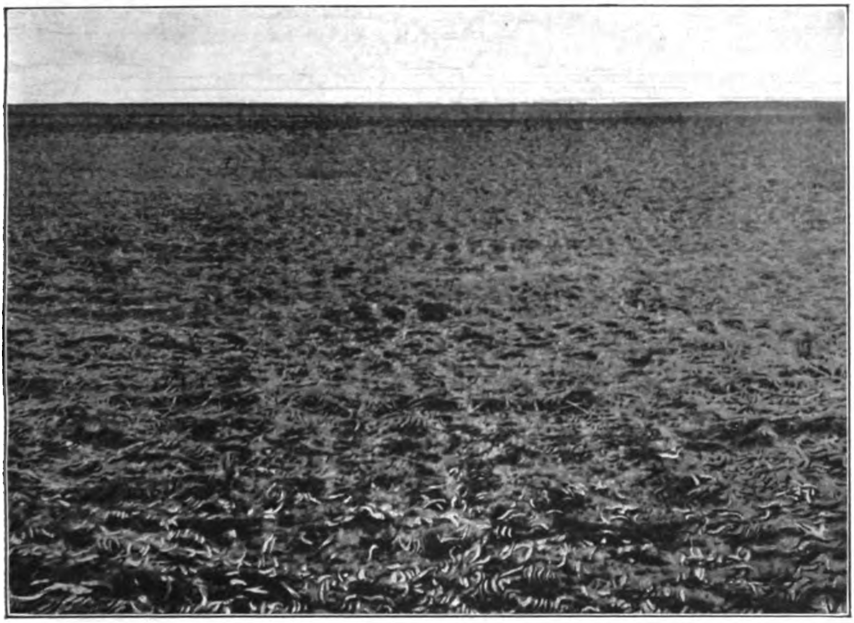

FIG. 1.—WHEAT FIELD TOTALLY DESTROYED BY THE SPRING GRAIN-APHIS (TOXOPTERA GRAMINUM).

Contrast with uninjured portion of field shown in figure 2. (Original.)

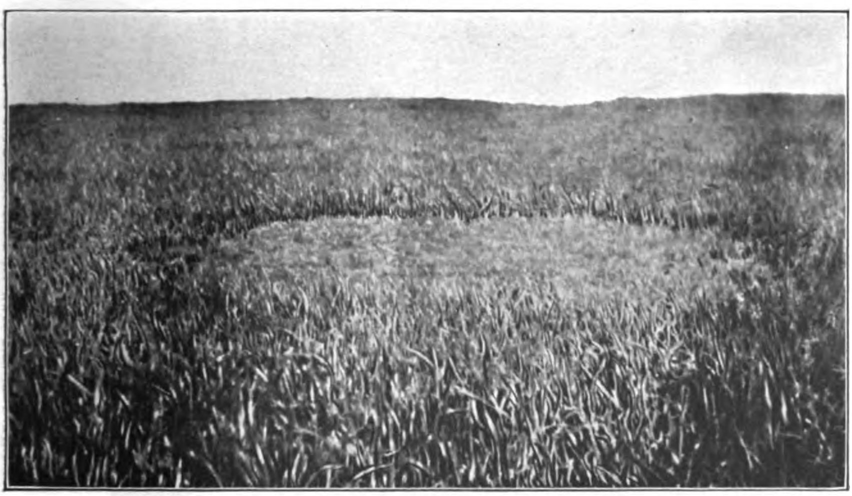

FIG. 2.—CIRCULAR SPOT IN WHEAT FIELD WHERE GROWING GRAIN HAS BEEN DESTROYED BY THE SPRING GRAIN-APHIS.

The growing grain on these circular areas is as completely destroyed as in the field shown in figure 1. Increasing in size and number, the spots come to include whole fields. (Original.)

From here the junior author made a trip into northwestern and northeastern Kansas and south-central Nebraska to determine the northern limit of destructive infestation. The following places were visited: Solomon, Dickinson County, Kans.; Beloit, Mitchell County, Kans.; Lenora, Norton County, Kans.; and Kearney, Buffalo County, Nebr. The infestation at all of these places was very slight and no damage was done. At two places only, Solomon and Beloit, were parasites found.

The senior author in the meantime proceeded to Great Bend, Barton County; Dodge City, Ford County; Garden City, Finney County; and Syracuse, Hamilton County—all in Kansas. The object of this trip was to see how far Toxoptera had spread to the westward. It was found at all of the above points, doing considerable injury; at Syracuse an unirrigated field of oats of 10 acres was found bordering an irrigation ditch. Along this ditch was a ragged border from 10 to 30 or 40 feet in width of vigorously growing oats where the "green bug" had apparently done no injury, while beyond this border, where the moisture from the ditch had not penetrated, the loss was total. In another case in the same locality, a part of the wheat in an unirrigated field came up in the fall and the rest not until the following spring; the former was uninjured by "green bugs," while the latter was killed. From Syracuse the senior author proceeded to Wellington, Kans., to join Mr. Ainslie.

In a letter dated June 5, 1907, Prof. C. P. Gillette states that he made a trip into the Arkansas valley early in the spring and found Toxoptera doing very serious injury to wheat fields; to such an extent was this the case that he advised some of the farmers to plow up some of their fields and plant other crops. Following this trip there was a heavy snowstorm and the "green bugs" were greatly diminished in numbers, though at the date of his writing (June 5) Toxoptera was abundant in the fields.

On July 9 Prof. Gillette sent us badly parasitized Toxoptera on blue grass from Fort Collins, Colo., with the statement that the "green bug" had largely disappeared from the grain fields in that locality.

Mr. Ainslie remained in the vicinity of Wellington, Kans., from the last week of April to the 21st of May, at which date he was joined by the senior author and went south to Kingfisher, Okla. The conditions found there were serious in the extreme, most of the grain fields being bare and many had been plowed and displaced by other crops. Between Wellington, Kans., and Kingfisher, Okla., a strip of country was encountered by them about 30 miles in width, beginning above Medford, Okla., with Pond Creek about midway between, and extending almost to Kremlin, Okla., over which the injury from Toxoptera was not nearly so great as in the country both to the

north and south. This area was investigated by Mr. Ainslie on the 23d of May. There was plenty of evidence of Toxoptera attack. Some fields were killed outright and others badly spotted, but a number of fields were little injured. No particular reason could be assigned for this condition of the fields, and this area, with a few interruptions, extended on to the west indefinitely. This belt extending across the wheat-growing section of Oklahoma was evidently observed by Mr. Sanborn, who stated in his notes, copies of which were furnished by Prof. Conradi, under date of March 29, 1907, "Northern boundary of parasitized infestation is between Kingfisher and Enid." Again, under date of March 30, "Pondcreek, Okla. Doing great damage, in large spots, here. There lies a peculiar feature between this and Kingfisher. At these two points the infestation was about equal. Enid has no damage yet."

Mr. Ainslie now started northward to trace Toxoptera to its most northerly point in the United States and to learn to what extent its parasite occurred with it, stopping at the following places: Kingman, Kingman County, Kans.; Hutchinson, Reno County, Kans.; Sterling, Rice County, Kans.; Scott, Scott County, Kans.; Great Bend, Barton County, Kans.; Oakley, Logan County, Kans.; Colby, Thomas County, Kans.; Goodland, Sherman County, Kans.; Manhattan, Riley County, Kans.; Lincoln, Lancaster County, Nebr.; Plainview, Pierce County, Nebr.; Dixon, Dixon County, Nebr.; Sheldon, O'Brien County, Iowa; Mason City, Cerro Gordo County, Iowa; Dodge Center, Dodge County, Minn.; Rochester, Olmsted County, Minn.; Brookings, Brookings County, S. Dak.; Aberdeen, Brown County, S. Dak.; Fargo, Cass County, N. Dak.; East Grand Forks, Polk County, Minn.; Hallock, Kitson County, Minn.; Grafton and Park River, Walsh County, N. Dak.; Larimore, Grand Forks County, N. Dak.; and Casselton, Cass County, N. Dak. He reached the last-mentioned place on August 5, after which he returned to Washington, D. C.

Except at Kingman, Hutchinson, Sterling, Great Bend, and Manhattan, Kans., Mr. Ainslie found but little damage resulting from Toxoptera, the most striking feature being the fact that parasites were found associated with Toxoptera at each point visited with the following exceptions: Goodland, Kans., very few Toxoptera in this immediate vicinity; Lincoln, Nebr., no Toxoptera found; Brookings, S. Dak., 2 to 3 Toxoptera only seen; Aberdeen, S. Dak., no Toxoptera found; Fergus Falls, Minn., only 1 Toxoptera observed here. The significant feature of this is that no parasites were introduced artificially at any of these points outside of Kansas.

From statements made by Prof. J. M. Stedman, who was professor of entomology at the University of Missouri at this time, it appears that Toxoptera was swept over the border from Oklahoma and Kansas into southwestern Missouri. Prof. Stedman states that there were from six to eight counties in the southwestern corner that were very

badly infested; outside of these counties the infestation was slight. He received very few if any reports of its occurrence north of the Missouri River. It probably occurred in the northern part of the State also, as the bureau received a report, with specimens, of injury to oats at Weaver, Lee County, Iowa, and Mr. C. N. Ainslie found it occurring in small numbers at several points in northwestern Iowa.

From reports received by this bureau it seems that Toxoptera was very abundant in northern Illinois, confining its injuries chiefly to oats. Mr. Edgar McGee, of Sciota, McDonough County, Ill., sent us specimens July 5 which proved to be Toxoptera, and in a letter dated July 29 he stated that it was very widespread, that his and adjoining counties were badly infested, and that some fields of oats were so seriously injured that the owners had plowed them under and planted other crops. The yield in that locality, from Mr. McGee's report, seems to have been greatly reduced.

At Sandwich, Dekalb County, Ill., there was apparently considerable damage to oats; no specimens were received; the injury in all probability was, however, due to Toxoptera. To quote from a letter from Mr. Clark Graves, bearing date of July 12:

> I have today mailed to you, under separate cover, a fair sample of the oats of this vicinity, and I think from general appearances that the crop will be shortened half on account of the green bug. The bugs have now disappeared, and it would seem that the late oats have suffered considerably more than the early ones.

There were no specimens of plant-lice in this material from Mr. Graves.

A report, with specimens, was received from Manteno, Kankakee County, Ill., which stated that that section had suffered considerably from "green-bug" attack.

We have only one record of serious injury from Indiana in 1907 that can without doubt be attributed to Toxoptera. This was in a small field of oats just outside the limits of Indianapolis. The junior author examined this field and found that over an acre had been seriously affected, part of it being entirely destroyed. The "green bug" disappeared from the oats before the latter headed out, probably overcome by Aphidius and other enemies. This infestation apparently originated from rank bluegrass growing along one side of the field. Later in the season, when the oats had been harvested, Toxoptera could be found along this margin on the bluegrass, where the sexes appeared and eggs were produced. Toxoptera was found at other points in Indiana, but only in small numbers.

Mr. T. H. Parks, of this bureau, states that in the latter part of June, 1907, the oats on his father's farm in Pickaway County, Ohio, were badly damaged by aphides. He states that parts of some fields in the neighborhood were scarcely worth cutting. Aphides were very abundant on the plants and parasitized aphides were very plentiful also. The oats plants that were badly infested turned brown, and

before they were ready to head out the aphidids disappeared. This was probably due to the presence of the parasites. Wheat was not attacked or injured by these aphides. Mr. Parks did not have any of this material identified, and we can not say absolutely that this was *Toxoptera graminum* Rond., but the character of the attack, the sudden disappearance of the aphidids, and the fact that they did not disturb wheat coincide with our observations on this insect in this latitude and to us clearly point to Toxoptera as the originator of the trouble.

Part of the trouble referred to in letters cited in Bulletin 210 of the Ohio Agricultural Experiment Station was, in all probability, due to "green-bug" attack, since from our own observations on this species in northern latitudes a part of this injury appears to be characteristic of Toxoptera.

North and South Carolina also suffered somewhat from the depredations of this insect in 1907. The senior author made a trip into this section, reaching Sumter, S. C., April 17, 1907. He found that all fields of oats, the only grain sown, were more or less affected; here and there brown areas occurred, showing the characteristic work of Toxoptera. This condition was noticeable from Sumter, S. C., to Charlotte, N. C., indicating that the infestation was general. Both *Macrosiphum granaria* Buckt. and *Toxoptera graminum* Rond. were present, but the latter was by far the more numerous. There were very few parasites or coccinellids in evidence. In a letter dated June 18 Mr. E. C. Haynsworth, of Sumter, stated that soon after the senior author's visit in April the weather became warmer and Toxoptera disappeared very rapidly.

In some parts of North Carolina the injury was quite serious. Mr. Franklin Sherman, jr., of the North Carolina Department of Agriculture, has kindly placed his notes on this outbreak at our disposal. He stated that the worst area of infestation centered about Winston-Salem, in Forsyth County, N. C., although some injury was also inflicted in Guilford, Davie, and Rowan counties in the same State, some fields being almost totally destroyed. Parasites were present, though not in sufficient numbers to hold Toxoptera in check.

The senior author went directly from Sumter, S. C., to Winston-Salem, N. C., reaching the latter place April 19, where he was met by Mr. Sherman, and they went over the ground together. A number of fields were examined, ranging from slightly infested to totally destroyed. In some fields of wheat, where there had been quantities of volunteer oats, the infestation was more severe. Parasites were present in great abundance in some fields, but they did not appear to have checked the pest in time to save all of the fields.

The senior author thus summarizes this outbreak:

From a study of the entire neighborhood it seems quite evident that the outbreak of Toxoptera in the vicinity of Winston-Salem was primarily due to the presence of

FIG. 1.—STAND ON WHICH REARING EXPERIMENTS WERE CARRIED OUT IN REARING THE SPRING GRAIN-APHIS. (ORIGINAL.)

FIG. 2.—AREA ON GROUNDS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE, AT WASHINGTON, D. C., WHERE THE SPRING GRAIN-APHIS USUALLY OCCURS ON BLUEGRASS IN EXCESSIVE ABUNDANCE DURING SUMMER.

The area infested is indicated by a +. (Original.)

fields of fall oats and more or less volunteer grain in other fields, all of which constituted breeding grounds for the pest during the preceding autumn, and from which winged individuals migrated and established new colonies in other fields; these, owing to influence of weather on the development of parasites, caused the most of the injury in wheat.

We received a letter with specimens from Mr. L. M. Smith, Mr. Sherman's assistant, at Newport, Carteret County, N. C., stating that he found a small field of oats in the outskirts of town that was considerably damaged by Toxoptera. This county is on the coast and Newport has an elevation of 19 feet. From this it seems that in all probability Toxoptera covered the entire State.

The senior author also found Toxoptera in destructive abundance at Midlothian, Chesterfield County, Va., in a small meadow of orchard grass. Mr. J. L. Phillips, the State entomologist, reported a slight outbreak at Cloverdale, Botetourt County, Va., in rye, and stated that considerable damage had been done in some parts of the field. One undetermined Aphidius was found at Midlothian, while none was reported from Cloverdale.

There was an outbreak of Toxoptera in the bluegrass lawns north of the buildings of the Department of Agriculture at Washington, D. C., in July, 1907. The infested area (see Pl. II, fig. 2) was apparently confined to the space of about an acre, where it was excessively abundant; outside of this area practically no Toxoptera could be found. This offered a good opportunity to test spray materials and a number of experiments of this kind were carried on.

Dr. Howard, personally, found Aphidius present in this infested area though in very limited numbers. In all probability this was *Aphidius avenaphis* Fitch, as we have since found this species in this exact locality but at no time have we found *A. testaceipes* Cress., which, until Mr. Viereck revised this group, had been considered to be *Lysiphlebus tritici* Ashm. We did not, in 1907, find any species of Aphidius present and did not know that Dr. Howard had done so, as he soon after sailed for Europe and at the time Circular 93 of this bureau was published the statement as to its nonoccurrence was not called to his attention in time to be corrected and he did not inform us of his find, supposing that we knew of it already. Mr. Kelly, however, found *Allotria* sp. present there in 1907, and we have since found this to be a parasite of Aphidius, which may account for the fact that the latter was present in such limited numbers. In 1908 *Aphidius avenaphis* was quite plentiful there, although specimens were not preserved, while *Allotria* sp. was found sparingly on the grounds elsewhere in the vicinity. As Toxoptera attracted no attention in this area on the grounds of the Department of Agriculture in 1909 we have no records for that year. In 1910 Toxoptera was again injuriously abundant on the same area and no Aphidius could be found, while *Allotria* sp. was still in evidence. It seems possible that condi-

tions were unfavorable for the rapid increase of Allotria in 1908, which conditions would prove favorable for Aphidius and also unfavorable for its host, the Toxoptera. This infested area on the department grounds in Washington has proved to be of considerable interest, as the fluctuations of Toxoptera there, as well as those of its parasite Aphidius and the secondary parasite Allotria, must coincide with what is going on in similar places over the country, thus forming small secluded breeding areas where Toxoptera survives throughout the summer, more especially in the South. The area in question is a depression covered chiefly by bluegrass, occupying perhaps half an acre, surrounded on all sides except the south by shade trees (See Pl. II, fig. 2.) It is rather more moist and therefore cooler in summer than other portions of the grounds and in common with the rest is kept closely mown. An underground steam pipe which affords heat for a large number of greenhouses extends along the southern and eastern margins; the ground above this pipe is always much warmer than the surrounding area during winter, the snow disappearing first and the grass in that location starting much earlier in spring. So far we have not found that these latter conditions have any influence in enabling the Toxoptera to breed viviparously during the winter. Even when the Toxoptera was excessively abundant here none could be found in the bluegrass-covered grounds only a few yards away, except in 1910, when it was quite numerous about the Washington Monument some four blocks away. Because of its isolation—there are no grain fields within miles on the Maryland side of the Potomac River and the department experiment farm at Arlington, Va., has the only grain for miles on the west side of the river—and because these last had never suffered from Toxoptera attack, this area became of too much importance as a convenient field of observation and experimentation to make an attempt at experimenting with the importation of great numbers of Aphidius desirable. There is every reason for believing that it is in similar favorable localities that Toxoptera passes the summer months in the southwestern portion of the country, where, as observations have shown, it is not able to withstand the high temperatures of the open fields.

Toxoptera has been studied throughout the summer in the Southwest with much difficulty, and not at all satisfactorily for the reason that we have been unable to keep it under continuous observation in the open fields.

Except in cases of local outbreaks here and there over the country there has been no serious injury to grain crops by the "green bug" since 1907. Many additional localities for the species have been added since then, however, and it now appears to cover almost the entire United States, excepting perhaps New York and the New England States. (See fig. 4, p. 19.)

### LOSSES FROM DEPREDATIONS IN 1907.

It is impossible to arrive at the actual monetary loss occasioned by this fearful outbreak, as no data have been collected with this special end in view, either by the State or National governments. Several points must be considered in making such an estimate. Large areas planted to wheat and oats were abandoned, part being planted to other crops and the remainder left lying idle. Much money that was entirely lost was expended in seed, fertilizers, preparing the seed bed and planting; of course all of the fertilizer would not be lost where another crop followed. The greatest source of loss came through partial or actual destruction of the young wheat, thus greatly reducing the yield.

The Bureau of Statistics of the Department of Agriculture kindly compiled the following table for us, which will shed some light on the amount of loss probably attributable to the "green bug."

TABLE I.—*Losses from depredations by the spring grain-aphis in 1907 in Kansas, Oklahoma, and Texas.*

| | Winter wheat. | | | | | Oats. | | |
|---|---|---|---|---|---|---|---|---|
| | Acreage planted in fall of preceding year (preliminary). | Per cent abandoned. | Acreage harvested (revised). | Yield per acre. | Total production. | Acreage. | Yield per acre. | Total production. |
| **KANSAS.** | | | | | | | | |
| | | | | *Bush.* | *Bushels.* | | *Bush.* | *Bushels.* |
| 1905 | 5,645,000 | 6.3 | 5,290,000 | 13.9 | 73,527,000 | 858,000 | 27.1 | 23,248,000 |
| 1906 | 5,702,000 | 10.0 | 5,132,000 | 15.3 | 78,517,000 | 1,060,000 | 23.6 | 24,780,000 |
| 1907 | 5,930,000 | 4.8 | 5,645,000 | 11.3 | 63,788,000 | 1,092,000 | 15.0 | 16,380,000 |
| 1908 | 5,930,000 | 2.5 | 6,108,000 | 12.8 | 78,182,000 | 994,000 | 22.0 | 21,868,000 |
| 1909 | 6,173,000 | 4.5 | 5,895,000 | 14.5 | 85,478,000 | 964,000 | 28.2 | 27,185,000 |
| 1910 | 6,195,000 | 35.0 | 4,300,000 | 14.2 | 61,060,000 | 1,400,000 | 33.3 | 46,620,000 |
| Average | ........ | ...... | ........ | ...... | 73,425,000 | ........ | ...... | 26,680,000 |
| **OKLAHOMA.** | | | | | | | | |
| 1905: | | | | | | | | |
| Ind. T | 286,000 | 5.5 | 270,000 | 10.0 | 2,703,000 | 202,000 | 36.0 | 7,258,000 |
| Okla | 1,493,000 | 3.9 | 1,435,000 | 8.2 | 11,764,000 | 294,000 | 33.0 | 9,717,000 |
| 1906: | | | | | | | | |
| Ind. T | 249,000 | 3.2 | 241,000 | 12.0 | 2,890,000 | 218,000 | 34.2 | 7,447,000 |
| Okla | 1,403,000 | 5.0 | 1,333,000 | 14.0 | 18,664,000 | 350,000 | 34.4 | 12,040,000 |
| 1907: | | | | | | | | |
| Ind. T | 216,000 | 28.0 | ........ | ...... | ........ | ........ | ...... | ........ |
| Okla | 1,235,000 | 35.0 | 959,000 | 9.0 | 8,631,000 | 418,000 | 15.0 | 6,270,000 |
| 1908 | 1,379,000 | 2.3 | 1,347,000 | 11.6 | 15,625,000 | 450,000 | 25.0 | 11,250,000 |
| 1909 | 1,241,000 | 6.5 | 1,225,000 | 12.8 | 15,680,000 | 550,000 | 29.0 | 15,950,000 |
| 1910 | 1,604,000 | 3.0 | 1,556,000 | 16.3 | 25,363,000 | 632,000 | 36.5 | 23,068,000 |
| Average | ........ | ...... | ........ | ...... | 16,887,000 | ........ | ...... | 15,500,000 |
| **TEXAS.** | | | | | | | | |
| 1905 | 1,319,000 | 5.3 | 1,249,000 | 8.9 | 11,118,000 | 914,000 | 31.4 | 28,713,000 |
| 1906 | 1,266,000 | 3.0 | 1,228,000 | 11.5 | 14,126,000 | 914,000 | 34.8 | 31,823,000 |
| 1907 | 1,266,000 | 70.0 | 380,000 | 7.4 | 2,812,000 | 500,000 | 19.0 | 9,500,000 |
| 1908 | 988,000 | 6.5 | 924,000 | 11.0 | 10,164,000 | 750,000 | 28.9 | 21,675,000 |
| 1909 | 929,000 | 27.5 | 555,000 | 9.1 | 5,050,000 | 615,000 | 18.7 | 11,500,000 |
| 1910 | 1,295,000 | 3.3 | 1,252,000 | 15.0 | 18,780,000 | 695,000 | 35.0 | 24,325,000 |
| Average | ........ | ...... | ........ | ...... | 10,342,000 | ........ | ...... | 21,256,000 |

If we average the 5-year period and calculate the loss on this basis for 1907, it will be seen that the total crop for Kansas, Oklahoma, and Texas fell about 50,000,000 bushels short of this average—both wheat and oats being considered. Seventy per cent of the Texas wheat acreage was abandoned.

This does not represent the loss as it actually occurred in various parts of the States, as some parts of each State were more badly affected than others and the good parts would bring up the yield for the poorer portions. Sumner County, Kans., is a good illustration of this. It is located in the extreme southern portion of the State and was in the badly infested districts. To quote from a letter from Mr. George H. Hunter, of Wellington, Kans., dated February 6, 1908:

> I wish to explain that our crop of winter wheat in Sumner County for the year 1907 amounted to 1,909,574 bushels; this is our latest estimate, while the general average is about four and one-half million bushels for Sumner County, and that would be a safe basis for you to figure on. According to our acreage last year, if it had not been for the green bugs, I think we would have had at least four to four and one-half million bushels of wheat.

## THE SITUATION IN 1911.

The winter and spring of 1910–11 west of the Mississippi River, but not east of it, was such as would tend to bring about another invasion from the pest. Some injury was reported, accompanied by specimens, from Pecos River valley in southeastern New Mexico. Mr. J. T. Monell of this bureau, however, visited the locality in April and reported the pest as having disappeared without doing serious injury. The material received was almost universally parasitized by *Aphidius testaceipes* Cress., which probably overcame the Toxoptera before its occurrence reached the magnitude of an invasion.

There was also a limited incipient outbreak in eastern Oklahoma, which was investigated by Mr. Kelly. Here, too, the parasites apparently gained supremacy before serious injury was done, except perhaps in a few isolated cases.

There is little doubt that the unusual and excessively high temperature for even a mild winter that prevailed throughout the Southwest during a portion of the winter months was sufficient to revive the parasites as well as to aid their host, and thus bring about conditions that enabled the parasites to prevent the aphidids from increasing in numbers to a point where they were beyond their control.

## FOOD PLANTS.

This insect has a very wide range of host plants and can on that account find fresh food at any season of the year. In this way it is enabled to perpetuate itself over vast areas of country and under almost every variety of climate.

Rondani, who first described the species in 1852, gives the following list of host plants: Oats (*Avena sativa*); wheat (*Triticum vulgare*); spelt (*Triticum spelta*); *Arrhenatherum elatius* (*Avena elatior*); couch grass (*Triticum repens*); *Hordeum murinum; Lolium perenne; Capriola* (*Cynodon*) *dactylon;* soft chess (*Bromus hordeaceus*) (*mollis*); and corn (*Zea mays*). He states also that Toxoptera had been found quite abundant upon the foliage of rice (*Oryza sativa*) and common barley (*Hordeum vulgare*). We find no other references to its being found upon rice. In 1863 Passerini adds sorghum (*Andropogon* sp.) and he also observed it on barley.

Macchiati, in 1882, added the following hosts: *Dactylis glomerata*, *Bromus erectus*, and *B. villosus* (*maximus*); in 1883 he added *Triticum villosum*, *Avena fatua*, and *A. barbata;* in 1885, *Poa annua*.

Del Guercio, in 1906, mentions it as occurring upon buckwheat (*Fagopyrum esculentum*). This is the first and only reference we have found in which it has been accused of infesting plants other than those belonging to the Gramineæ.

Toxoptera was first observed upon wheat and oats in the United States. In 1889 the senior author observed it feeding upon rye and in 1890 he found it plentiful at Lafayette, Ind., upon *Dactylis glomerata*. In 1907 he found it destructively abundant upon the same grass at Midlothian, Va. This infested field was from 4 to 5 miles from wheat, oats, or rye fields. In Insect Life,[1] he states that Toxoptera will live upon the leaves of all kinds of grains, including corn, during summer. In 1902 he found Toxoptera feeding upon cheat (*Bromus secalinus*) and rye grass (*Elymus canadensis*) at Peotone, Ill.

The junior author found it quite abundant on volunteer corn plants among oats on April 2, 1907, at Hobart, Okla. A cornfield near a badly infested wheat field was found to be suffering also. Mr. C. N. Ainslie of this bureau, on April 4 of the same year, at Kingfisher, Okla., found a cornfield that was seriously injured by Toxoptera. Farmers in Oklahoma were very much disturbed over the prospect that the corn also would be swept away by the "green bug," but later developments proved that it was not a serious pest to corn. The junior author found *Hordeum pusillum* and *Alopecurus geniculatus* badly infested on April 12 at Kingfisher, Okla., and *Agropyron occidentale* was found harboring the pest in large numbers at Hooker, Okla., in May. The senior author, Mr. Ainslie, and Prof. E. A. Popenoe,

[1] Insect life, Div. Ent., U. S. Dept. Agr., vol. 4, p. 245.

of Kansas, also found the *Hordeum pusillum* much infested later in the season. In July there was an outbreak of Toxoptera on bluegrass (*Poa pratensis*) on the grounds of the United States Department of Agriculture, Washington, D. C. Later in the season the junior author found it on bluegrass in the fields about Richmond, Ind. In the fall of the same year (1907) this was the only plant on which the sexes and eggs could be found. In fact, for Indiana, Illinois, Ohio, and more northern localities bluegrass appears to be the normal host, and the "green bug" is readily found upon it at any time in the year even when it can be found only sparingly upon any other plant.

A number of new host plants were added to the list in 1908. Mr. Kelly, of this Bureau, found Toxoptera feeding freely in the fields upon *Hordeum jubatum* and *Distichlis spicata* in Montana and upon a species of Andropogon in Colorado. Mr. Ainslie found it breeding freely in the fields upon *Hordeum jubatum*, *H. cæspitosum*, *H. nodosum*, *Elymus striatus*, *Agropyron tenerum*, *Bromus unioloides*, *B. porteri*, *Stipa viridula*, and *Polypogon monspeliensis* about Artesia, N. Mex. In one instance Mr. Ainslie found several alfalfa plants (*Medicago sativa*) with colonies of Toxoptera upon them, as many as 21 specimens being observed on a single leaf. This seems very unusual and we have no other records of its occurrence on this plant. Prof. C. P. Gillette, of Fort Collins, Colo., found it infesting *Agropyron occidentale*, and in 1907 he found it feeding upon bluegrass. During the summer of 1908 Toxoptera was found by the junior author to breed freely upon *Dactylis glomerata*, *Eleusine indica*, *Eragrostis pilosa*, *E. megastachya*, *Sporobolus neglectus*, *Agropyron repens*, *Elymus virginicus*, *E. canadensis*, and *Bromus secalinus*, in his rearing cages at Richmond, Ind.

In 1909 and 1910 a few more plants were added to the list. Mr. Ainslie found it breeding freely upon *Hordeum murinum* in Arizona and upon *Agropyron occidentale* in New Mexico. Mr. Kelly found it breeding freely upon millet (*Chætocloa italica*) and upon Japanese millet (*Echinochloa crus-galli*) in Kansas. Mr. Harper Dean, jr., then of this bureau, found it feeding upon *Stipa leucotricha* in Texas. Mr. T. D. Urbahns, of this bureau, found that it bred readily in his cages at Dallas, Tex., upon Bermuda grass (*Capriola dactylon*), *Chætochloa viridis*, Johnson grass (*Sorghum halepense*), and upon rice (*Oryza sativa*).

During the summer of 1909 Mr. T. H. Parks, of this bureau, and the junior author observed that Toxoptera bred freely upon *Elymus striatus*, *Juncus tenuis*, *Poa compressa*, *Bromus commutatus*, *B. tectorum* (?), *B. inermis*, sheep's fescue (*Festuca ovina*), hard fescue (*F. duriuscula*), meadow fescue (*F. elatior*), various-leaved fescue

(*F. heterophylla*), *F. rubra*, *Agropyron occidentale*, and Italian rye grass (*Lolium multiflorum*), in their rearing cages at Lafayette, Ind.

The following is a complete tabulated list of host plants[1] to date, in so far as our records show.

IN EUROPE.

Barley.
Corn.
Oats.
Rice.
Wheat.
Spelt.
Sorghum.
*Agropyron* (*Triticum*) *repens*.
*Avena barbata*.
*Avena elatior*=*Arrhenatherum elatius*.
*Avena fatua*.
*Bromus erectus*.
*Bromus maximus*=*B. villosus*.
*Bromus mollis*=*B. hordeaceus*.
*Capriola* (*Cynodon*) *dactylon*.
*Dactylis glomerata*.
*Fagopyrum esculentum*.
*Hordeum murinum*.
*Lolium perenne*.
*Poa annua*.
*Triticum villosum*.

IN AMERICA.

Barley.
Corn.
Oats.
Rice.
Rye.
Sorghum.
Spelt.
Wheat.
Alfalfa (*Medicago sativa*).
*Agropyron occidentale*.[2]
*Agropyron repens*.
*Agropyron tenerum*.[2]
*Alopecurus geniculatus*.[2]
Cheat (*Bromus secalinus*).[2]
*Bromus commutatus*.[2]
*Bromus inermis*.[2]
*Bromus porteri*.[2]
*Bromus tectorum* (?).[2]
*Bromus unioloides*.[2]
*Capriola dactylon*.
*Chætochloa italica*.
*Chætochloa viridis*.[2]
*Dactylis glomerata*.
*Distichlis spicata*.[2]
*Echinochloa crus-galli*.[2]
*Eleusine indica*.[2]
*Elymus canadensis*.[2]
*Elymus striatus*.[2]
*Elymus virginicus*.[2]
*Eragrostis megastachya*.[2]
*Eragrostis pilosa*.[2]
*Festuca duriuscula*.[2]
*Festuca heterophylla*.[2]
*Festuca ovina*.[2]
*Festuca elatior*.
*Festuca rubra*.[2]
*Holcus halpensis*.[2]
*Hordeum cæspitosum*.[2]
*Hordeum jubatum*.[2]
*Hordeum murinum*.
*Hordeum nodosum*.[2]
*Hordeum pusillum*.[2]
*Juncus tunuis*.[2]
*Lolium multiflorum*.[2]
*Poa compressa*.[2]
*Poa pratensis*.[2]
*Polypogon monspeliensis*.[2]
*Sporobolus neglectus*.[2]
*Stipa leucotricha*.[2]
*Stipa viridula*.[2]

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[1] During 1909 Mr. C. P. v. d. Merwl, Bloomfontein, Orange Free State, Africa, wrote us that he had found *Toxoptera graminum* attacking "Bermuda grass" and their native blue-grass (*Andropogon hirtus*).

[2] These are host plants not previously recorded.

## CHARACTER OF ATTACK.

The actual effect upon the plant, whether chemical or physiological, is not clearly understood. If a few Toxoptera be placed upon a perfectly healthy plant, in a few days the tissue in the immediate vicinity of the aphidids will take on a yellowish tinge; if the aphidids remain in one place for a considerable time and increase in numbers, the whole plant gradually turns yellow and dies, the leaves changing to reddish brown.

When the original source of infestation arises from some one or more points within a field, as described elsewhere in this paper, the plants take on a yellowish color in small, almost circular areas, (Pl. I, fig. 2) and as the Toxoptera increase in numbers the plants in the center die, becoming reddish brown, and the aphidids work outward in every direction from the center, gradually enlarging the spot until it may cover many acres. When a field is infested from without by migrating forms, the aphidids appear to spread evenly over the entire field and the whole gradually turns yellow, and in cases of severe outbreaks a whole field may die simultaneously. (See Pl. I, fig. 1.) These aphidids are essentially leaf-feeders, rarely if ever being found injuring the heads or fruiting parts of the plant.

Toxoptera appears to have a more strikingly disastrous effect upon wheat or oats plants than any of the other common grain aphidids. Seemingly when in no greater numbers than other species the plants will succumb more quickly to the attack of Toxoptera.

## VIVIPAROUS DEVELOPMENT.

*Toxoptera graminum*, as already shown, has been found to breed over a wide range of country, and its behavior, under the varying temperatures and climatic conditions prevailing over this vast territory, presents and opens up a broad field for investigation.

### IN THE SOUTH.

In northern latitudes the normal manner of reproduction among the Aphididæ is both sexually and asexually. In southern latitudes hese conditions, apparently, do not obtain, as here the normal means of reproduction seems to be asexually, each generation being composed entirely of viviparous females.

South of about the thirty-fifth parallel, except in high altitudes, it appears that Toxoptera breeds continuously throughout the year without the appearance of the true sexes. April 6, 1906, Mr. George I. Reeves, of this bureau, found the eggs of a plant-louse on wheat at Nashville, Tenn., and Mr. Kelly found males (fig. 6), females, and eggs of Toxoptera at Knoxville, Tenn., in December, 1908. The eggs found by Mr. Reeves may have been those of Toxoptera, but we

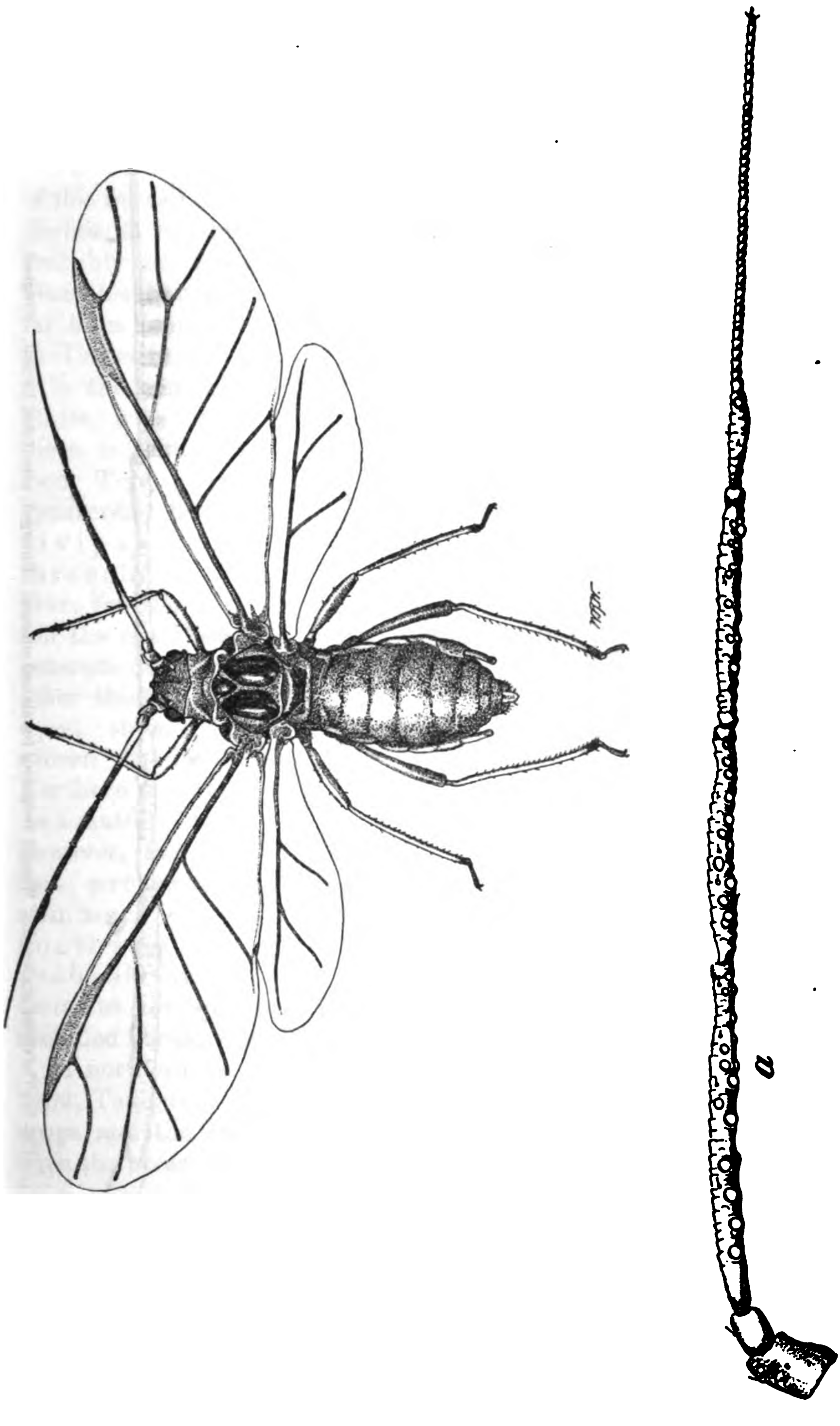


FIG. 6.—The spring grain-aphis (*Toxoptera graminum*): Male and antenna. Enlarged; actual size, 1.5 mm. (Original.)

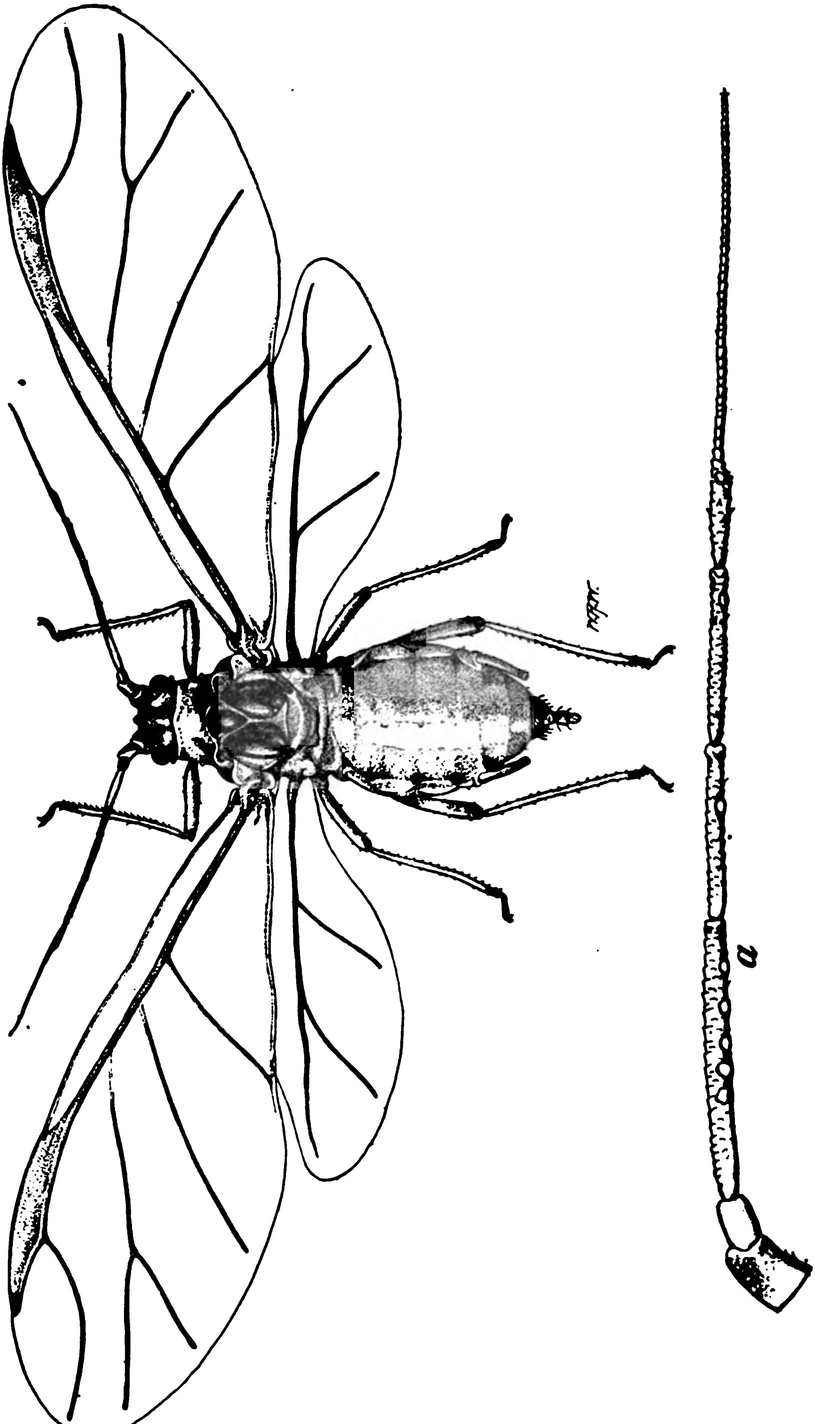


FIG. 7.—The spring grain-aphis: Winged viviparous female and antenna. Enlarged; actual size, 1.9 mm. (Original.)

can not be sure of the species as they were not reared. Winged and wingless viviparous females (figs. 7, 8) were, however, present at the time the eggs were found, as were also those of both Aphis (Siphocoryne[1]) and Macrosiphum. Mr. E. Dwight Sanderson obtained the males and oviparous females of *Macrosiphum granaria* Buckt. in Texas but only artificially in his rearing cages. Mr. R. A. Vickery, of this bureau, found males, females, and eggs of *Aphis maidi-radicis* Forbes at Salisbury, N. C. These instances mentioned above are probably the most southerly points at which oviparous forms of plant-lice have so far been found in the United States.

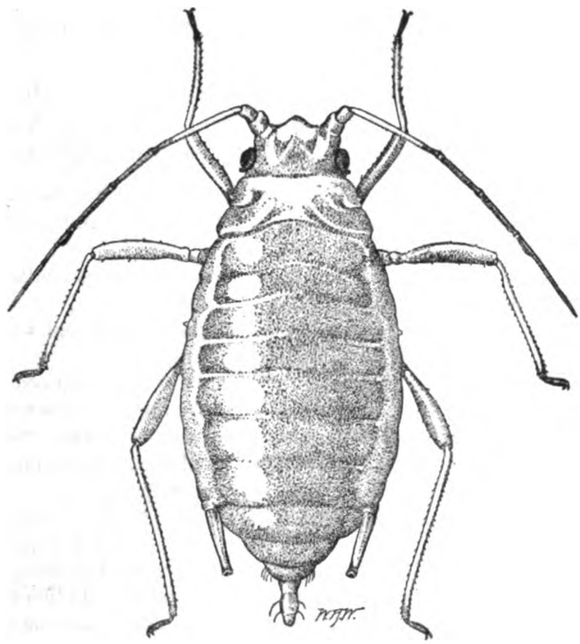

FIG. 8.—The spring grain-aphis: Wingless viviparous female. Enlarged; actual size, 2 mm. (Original.)

In the Southern States, wherever there is sufficient food, Toxoptera apparently breeds viviparously throughout the year; for this reason the number of generations here, other things being equal, should far exceed that in the Northern States. As a matter of fact, however, the dry, hot, protracted summers of the Southwest are probably disastrous to the species during the hot months, except perhaps in secluded nooks, where there is a supply of succulent host plants.

In northern Texas, as observed by Mr. Urbahns, during June of 1909, Toxoptera rapidly disappeared with the ripening of the grain crops and the approach of hot weather. Winged forms migrated with the breeze early in this month, and wingless forms soon perished from extreme heat and a shortage of green food in the field. Observations clearly showed that it was almost impossible for the "green bug" to live and reproduce in grain fields during the summer. While

[1] Probably *Siphocoryne avenæ* Fab. The use of the generic name Siphocoryne, as applied to this species, is questionable, and is not at present followed by many, perhaps the major portion, of the students of the Aphididæ. According to Schouteden (Ent. Soc. Belgique, vol. 12, p. 217, 1906, Catalogue Aphides de Belgique) it should be Aphis. Some of our best students, however, admit that this particular species, *avenæ*, is on the borderland between Siphocoryne and Aphis.

the temperature was above and precipitation below normal, during this particular season, the effect was so evident that there is reason to believe that under normal conditions these aphidids do not live in fields directly exposed to the sun during the summer months.

The table on pages 64–69 on daily reproduction, length of reproductive period, and longevity show a decided decrease in all of these for the summer months over those of spring and fall. The facts upon which these figures were based could be secured only by protecting the aphidids from exposure to the hot summer sun. Aphidids exposed without such protection were unable to live through the season, though special care was taken to furnish them with a supply of green food plants.[1]

Mr. Urbahns secured the following results by removing Toxoptera, together with its green food plants, from a shaded position and subjecting it to the temperature of loose, unshaded soil.

August 18, with the soil temperature at 145° F. in the sun, 12 Toxoptera on a wheat plant were exposed 30 seconds; 5 fell to the ground dead, 7 remained on the plant dead.

Three adults and 4 young on a wheat plant were similarly exposed for 30 seconds, after which time all were dead.

One winged and 4 wingless adults on a wheat leaf were exposed for 30 seconds, when they were found to be dead on the plant.

Thirteen adult aphidids on wheat plants were exposed for 15 seconds, 5 fell to the ground dead. After 30 seconds exposure the plant was removed to the shade; 6 more were then dead on the plant and 2 were alive between the leaves.

Soil temperature 118° F. (shaded by cloud). Nine aphidids on a wheat plant were exposed for 30 seconds, 2 died, and 7 remained alive.

A potted wheat plant bearing several hundred aphidids, the temperature being 114° F. in the shade, was removed from the shade for 5 minutes. A large percentage of the aphidids fell to the ground, some survived, but many died.

A potted wheat plant bearing several hundred aphidids was kept in the shade where the maximum temperature was 114° F. Next morning many of the aphidids were dead.

When the soil temperature was 116° F. shaded by a thin cloud, 3 aphidids on a plant were exposed for 60 seconds, 1 died, and 2 remained alive.

August 19, the soil temperature being 128° F. in the sun, 12 aphidids on a young plant were exposed for 30 seconds; 5 fell from the plant and died, while the other 7 were dead on the plant.

When the soil temperature was 130° F. in the sun 12 aphidids on a young plant were exposed for 20 seconds. All were then dead.

When the soil temperature was 128° F. in the sun 11 aphidids on a plant were exposed for 30 seconds; at the end of this time all were dead—4 fell to the ground, and 7 remained on plant.

At a soil temperature of 130° F. in the sun 8 aphidids on a plant were exposed for 15 seconds; all were then dead—3 fell to the ground, and 5 remained on the plant.

The results of these experiments prove that Toxoptera can not survive the summer in the open fields in sections of the country where the pest commits its most serious ravages with the greatest

[1] Mr. J. T. Monell suggests that this may be due as much or more to the hot, dry air as to the direct rays of the sun.

frequency. They also account for our inability to locate it in such territory during the summer months.

A careful search was made at different times for grasses that were actually serving as summer food plants. The only hope of finding such was in well shaded spots along streams, where, from all indications, Toxoptera would be sufficiently protected to live and reproduce throughout the summer.

At Plano, Tex., Toxoptera was rapidly disappearing from the fields in early June. By June 14 there was only a limited number of plants which still supported the remaining few of these aphidids and the latter were soon carried away by ants. When confined on green food plants and protected from their enemies by a large frame covered with thin cheesecloth Toxoptera lived until July 3. After this date it was apparently too hot for their existence. Out in the open, where young wheat and oats plants were sustained by frequent watering, they lived until July 15. After this date they apparently could not endure the summer temperature and no more were found. Since no reinfestation appeared up to November 30, it was quite evident that the aphidids had all perished.

On June 28 viviparous forms of this species were found rather abundantly in a small field of oats at McAlester, Okla. This field of a few acres in size was on the east slope of a rocky hill. A natural growth of timber surrounded the field and a few trees grew in its midst where rocks make cultivation impossible. Green vegetation was abundant in shaded places and along the creek one-half mile to the east. Conditions of this sort are certainly favorable for Toxoptera to live and reproduce throughout the summer as long as they find the food plants present. While these spots, favorable to Toxoptera, are characteristic of eastern Oklahoma, where, as has been stated, an incipient outbreak of the pest actually occurred in 1911, they are also found along streams in the central part of that State and in northern Texas. As there appears to be no resting or egg stage in the South, whenever there is a warm open winter these aphidids become very abundant and threaten the grain crops of this region.

## IN THE NORTH.

Farther north, in the vicinity of Lafayette, Ind., viviparous reproduction is confined to the months of April, May, June, July, August, September, October, and November. During mild winters, however, the species may breed viviparously throughout the year, as the senior author found it breeding in the open throughout January, February, and March, 1890, notwithstanding the fact that on January 24 the temperature fell as low as + 3° F.; on February 9, to + 6° F., and on March 6 to + 4° F. It appears that a temperature of about

zero, with no protection, is fatal to Toxoptera, except to the egg, but the fact that it withstood the winter in 1890 can easily be accounted for. That winter was unusually mild throughout, with the exception of the dates mentioned, and if one consults the weather records it

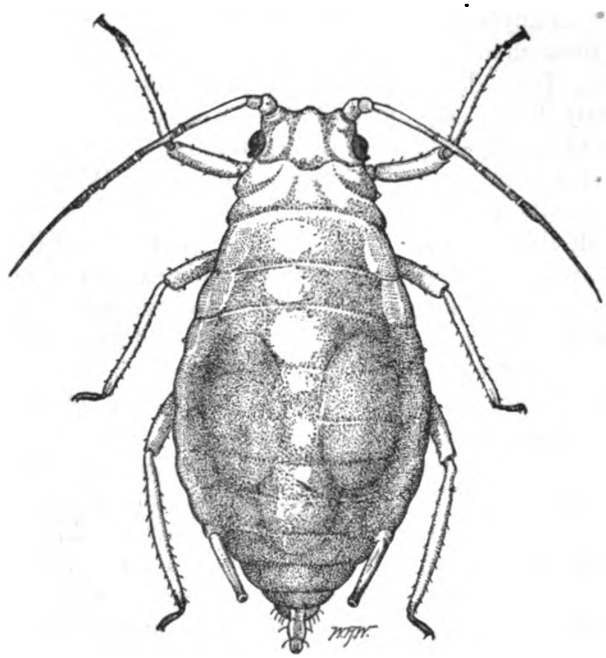

FIG. 9.—The spring grain-aphis: Oviparous female, showing eggs within the abdomen. Enlarged; actual size, 2.25 mm. (Original.)

will be found that on January 24 there were 3.5 inches of snow, February 9, 3.4 inches, and March 6, 4 inches. The covering of snow in each instance would appear to have been sufficient to protect the Toxoptera, as on December 8, 9, and 10, 1909, at Lafayette, Ind., the temperature fell as low as from $-1°$ F. to $-4°$ F. below zero, and plant-lice of all kinds, in the rearing cages out of doors, were killed, while those in a near-by wheat field, covered with several inches of snow, were found to be in good condition on December 13, at which time the cold spell was broken and the ground began to thaw.

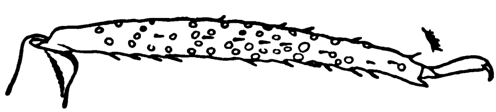

FIG. 10.—The spring grain-aphis: Hind tibia of oviparous female. Greatly enlarged. (Original.)

As a rule, Toxoptera breeds slowly in October and November, at which time the majority become oviparous females (figs. 9, 10) and males (fig. 6).

## REARING METHODS.

All of the rearing work, unless otherwise stated in the text, was conducted out of doors under as nearly normal conditions as it was possible for us to secure. The wheat plants on which the Toxoptera were confined were grown in flowerpots and covered with lantern globes, over the top of which was drawn a very thin fabric commercially known as swiss. The pots were placed on a rearing stand having one side hinged in such a manner that it could be let down in fair weather and closed up in case of gales or severe beating storms. This stand with its contents is illustrated in Plate II, figure 1. A thermograph was placed in this stand, and thus continuous records of temperature were secured.

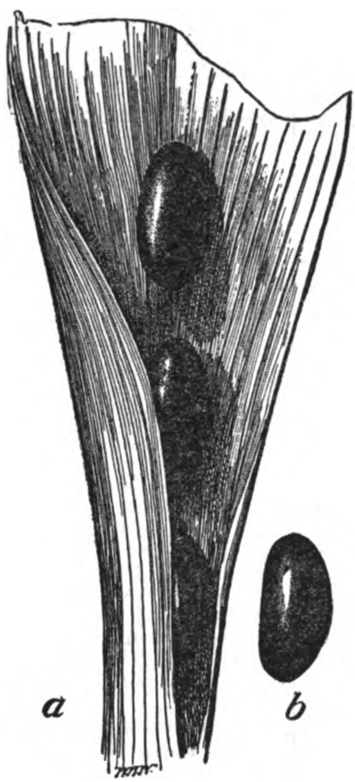


FIG. 11.—The spring grain-aphis: Eggs as deposited on leaf: a, Dorsal view; b, lateral view. Greatly enlarged. (Original.)

In the middle of the summer of 1907 two series of investigations were begun and were continued until December to determine the number of generations. In both 1908 and 1909 series of generation studies were begun in spring with the egg (fig. 11) and continued until the egg-laying forms appeared in the fall. In making these observations, the first individuals to hatch from the eggs in the spring were isolated; the first-born from these were in turn isolated, and this process was continued throughout the season until the egg-laying forms appeared. The last-born was also kept and the same mode of procedure continued until fall, as was the case in the line of the first-born. All young other than the first-born of the first series and the last-born of the second series were counted each day and destroyed. In this manner, each series being considered, we would arrive at the maximum and minimum number of generations. During these three years a vast amount of data, besides that on the number of generations, was thus accumulated. (See table, pp. 52–57.)

*First and last born generation series from an individual that hatched from the egg Mar. 27, 1908. Richmond, Ind.*

**[b=born. —=died or disappeared.]**

| Date (1908). | Temperature. | | First-born generation series. | | | | | | | | | | | | | | | | | | | | | Last-born generation series. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | First generation. | Second generation. | Third generation. | Fourth generation. | Fifth generation. | Sixth generation. | Seventh generation. | Eighth generation. | Ninth generation. | Tenth generation. | Eleventh generation. | Twelfth generation. | Thirteenth generation. | Fourteenth generation. | Fifteenth generation. | Sixteenth generation. | Seventeenth generation. | Eighteenth generation. | Nineteenth generation. | Twentieth generation. | Twenty-first generation. | Second generation. | Third generation. | Fourth generation. | Fifth generation. | Sixth generation. | Seventh generation. | Eighth generation. | Ninth generation. | Tenth generation. |
| | °F. | °F. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mar. 27 | 78 | 53 | b | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | 75 | 51 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | 51 | 36 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | 46 | 30 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | 53 | 41 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 1 | 59 | 47 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | 59 | 29 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 42 | 24 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | 63 | 29 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | 59 | 45 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | 68 | 36 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | 70 | 45 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 68 | 40 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | 55 | 35 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 60 | 46 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | 59 | 42 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | 62 | 27 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | 74 | 34 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | 77 | 47 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | 71 | 57 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | 57 | 31 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | 65 | 32 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | 63 | 55 | 2 | b | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | 70 | 50 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 68 | 39 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | 68 | 33 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | 79 | 35 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | 79 | 52 | 5 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | 71 | 60 | 4 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | 74 | 61 | 5 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | 80 | 53 | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | 67 | 42 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | 54 | 38 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | 46 | 36 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 | 47 | 83 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| May | 1 | 56 | 29 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | 47 | 85 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | 55 | 37 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | 50 | 41 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | 52 | 49 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 6 | 76 | 49 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 7 | 63 | 41 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 8 | 49 | 41 | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 9 | 65 | 42 | 5 | 2 | b | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 10 | 73 | 44 | | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 11 | 76 | 45 | 8 | 8 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 12 | 80 | 60 | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 13 | 80 | 55 | | 6 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 14 | 84 | 57 | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 15 | 85 | 59 | 3 | 7 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 16 | 86 | 52 | 2 | 4 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 17 | 87 | 54 | 2 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 18 | 77 | 61 | | | 2 | b | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 19 | 68 | 54 | 5 | 7 | 6 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 20 | 76 | 54 | | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 21 | 79 | 50 | 1 | 3 | 4 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 22 | 81 | 57 | 1 | 1 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 23 | 83 | 58 | 0 | 2 | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 24 | 85 | 55 | 0 | 4 | 5 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 25 | 92 | 55 | 0 | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 26 | 86 | 66 | 1 | 5 | 8 | 2 | b | | | | | | | | | | | | | | | | | | | b | | | | | | |
| | 27 | 88 | 57 | 0 | | | 4 | 0 | | | | | | | | | | | | | | | | | | | 0 | | | | | | |
| | 28 | 90 | 57 | — | 1 | 2 | 4 | 0 | | | | | | | | | | | | | | | | | | | 0 | | | | | | |
| | 29 | 90 | 62 | | 1 | 3 | 4 | 0 | | | | | | | | | | | | | | | | | | | 0 | | | | | | |
| | 30 | 78 | 62 | | 2 | 1 | 2 | 0 | | | | | | | | | | | | | | | | | | | 0 | | | | | | |
| | 31 | 71 | 55 | | 0 | 3 | 5 | 0 | | | | | | | | | | | | | | | | | | | 0 | | | | | | |
| June | 1 | 64 | 43 | | 1 | | | 0 | | | | | | | | | | | | | | | | | | | 0 | | | | | | |
| | 2 | 76 | 43 | | 0 | 0 | 3 | 0 | | | | | | | | | | | | | | | | | | | 2 | | | | | | |
| | 3 | 70 | 52 | | 0 | 4 | 6 | 0 | | | | | | | | | | | | | | | | | | | 4 | | | | | | |
| | 4 | 82 | 61 | | 1 | | | 2 | b | | | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | 84 | 50 | | 1 | 3 | 6 | 4 | 0 | | | | | | | | | | | | | | | | | | 0 | | | | | | |
| | 6 | 87 | 55 | | | | | 6 | 0 | | | | | | | | | | | | | | | | | | 2 | | | | | | |
| | 7 | 90 | 60 | | 1 | 1 | 4 | 4 | 0 | | | | | | | | | | | | | | | | | | 5 | | | | | | |
| | 8 | 86 | 64 | | 0 | 6 | 6 | 10 | 0 | | | | | | | | | | | | | | | | | | 6 | | | | | | |
| | 9 | 78 | 64 | | 0 | 3 | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 10 | 77 | 54 | | 0 | 1 | 2 | 0 | 0 | | | | | | | | | | | | | | | | | | 2 | | | | | | |
| | 11 | 72 | 43 | | 0 | 1 | 2 | | 0 | | | | | | | | | | | | | | | | | | 2 | b | | | | | |
| | 12 | 82 | 51 | | 0 | 0 | 1 | | 4 | b | | | | | | | | | | | | | | | | | 0 | 0 | | | | | |
| | 13 | 88 | 59 | | 0 | 0 | 3 | | 5 | 0 | | | | | | | | | | | | | | | | | 0 | 0 | | | | | |
| | 14 | 70 | 58 | | 0 | 1 | 2 | | 5 | 0 | | | | | | | | | | | | | | | | | 0 | 0 | | | | | |
| | 15 | 64 | 45 | | 0 | | | | 3 | 0 | | | | | | | | | | | | | | | | | 0 | 0 | | | | | |
| | 16 | 74 | 30 | | 0 | 2 | 0 | | 3 | 0 | | | | | | | | | | | | | | | | | — | 0 | | | | | |
| | 17 | 82 | 47 | | 0 | 0 | 2 | | 2 | 0 | | | | | | | | | | | | | | | | | | 0 | | | | | |
| | 18 | 90 | 65 | | — | 0 | 1 | | 7 | 0 | | | | | | | | | | | | | | | | | | 0 | | | | | |
| | 19 | 91 | 66 | | | 1 | 3 | | 12 | 0 | | | | | | | | | | | | | | | | | | 0 | | | | | |
| | 20 | 89 | 65 | | | | | | | 3 | b | | | | | | | | | | | | | | | | | 0 | | | | | |
| | 21 | 89 | 65 | | | 1 | 2 | | 7 | 8 | 0 | | | | | | | | | | | | | | | | | 0 | | | | | |

*First and last born generation series from an individual that hatched from the egg Mar. 27, 1908. Richmond, Ind.*—Continued.

| Date (1908). | Temperature. | | First-born generation series. | | | | | | | | | | | | | | | | | | | | | Last-born generation series. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | First generation. | Second generation. | Third generation. | Fourth generation. | Fifth generation. | Sixth generation. | Seventh generation. | Eighth generation. | Ninth generation. | Tenth generation. | Eleventh generation. | Twelfth generation. | Thirteenth generation. | Fourteenth generation. | Fifteenth generation | Sixteenth generation. | Seventeenth generation. | Eighteenth generation. | Nineteenth generation. | Twentieth generation. | Twenty-first generation. | Second generation. | Third generation. | Fourth generation. | Fifth generation. | Sixth generation. | Seventh generation. | Eighth generation. | Ninth generation. | Tenth generation. |
| | °F. | °F. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| June 22 | 91 | 64 | ..... | ..... | 0 | 0 | ..... | 5 | 6 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 5 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 23 | 93 | 68 | ..... | ..... | 0 | 0 | ..... | 3 | 4 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 24 | 94 | 67 | ..... | ..... | 0 | 0 | ..... | 4 | 8 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 5 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 25 | 79 | 52 | ..... | ..... | — | 0 | ..... | | | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | | b | ..... | ..... | ..... | ..... | ..... | ..... |
| 26 | 79 | 49 | ..... | ..... | ..... | 0 | ..... | 2 | 7 | 4 | b | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | 0 | ..... | ..... | ..... | ..... | ..... | ..... |
| 27 | 88 | 48 | ..... | ..... | ..... | — | ..... | | | 1 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | — | 0 | ..... | ..... | ..... | ..... | ..... | ..... |
| 28 | 89 | 52 | ..... | ..... | ..... | ..... | ..... | — | 4 | 4 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... |
| 29 | 81 | 60 | ..... | ..... | ..... | ..... | ..... | ..... | 4 | 8 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... |
| 30 | 82 | 54 | ..... | ..... | ..... | ..... | ..... | ..... | | | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... |
| July 1 | 89 | 52 | ..... | ..... | ..... | ..... | ..... | ..... | 4 | 4 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... |
| 2 | 89 | 57 | ..... | ..... | ..... | ..... | ..... | ..... | 4 | 3 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... |
| 3 | 82 | 64 | ..... | ..... | ..... | ..... | ..... | ..... | | 1 | 2 | b | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... |
| 4 | 82 | 66 | ..... | ..... | ..... | ..... | ..... | ..... | 1 | — | 3 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2 | ..... | ..... | ..... | ..... | ..... | ..... |
| 5 | 88 | 60 | ..... | ..... | ..... | ..... | ..... | ..... | 4 | ..... | 3 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2 | ..... | ..... | ..... | ..... | ..... | ..... |
| 6 | 91 | 66 | ..... | ..... | ..... | ..... | ..... | ..... | 1 | ..... | 3 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2 | ..... | ..... | ..... | ..... | ..... | ..... |
| 7 | 80 | 64 | ..... | ..... | ..... | ..... | ..... | ..... | 2 | ..... | 8 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3 | ..... | ..... | ..... | ..... | ..... | ..... |
| 8 | 78 | 48 | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | 5 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3 | ..... | ..... | ..... | ..... | ..... | ..... |
| 9 | 84 | 47 | ..... | ..... | ..... | ..... | ..... | ..... | — | ..... | 5 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... | ..... |
| 10 | 88 | 51 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 5 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2 | b | ..... | ..... | ..... | ..... | ..... |
| 11 | 91 | 54 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 4 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | 0 | ..... | ..... | ..... | ..... | ..... |
| 12 | 95 | 67 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3 | 2 | b | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | 0 | ..... | ..... | ..... | ..... | ..... |
| 13 | 92 | 63 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | | 2 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | — | 0 | ..... | ..... | ..... | ..... | ..... |
| 14 | 86 | 65 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3 | 3 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... |
| 15 | 79 | 57 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3 | 4 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... |
| 16 | 87 | 54 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3 | 1 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... |
| 17 | 90 | 66 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | | | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... |
| 18 | 84 | 71 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 6 | 2 | 3 | b | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... | ..... |
| 19 | 80 | 60 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | | | 0 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3 | ..... | ..... | ..... | ..... | ..... |
| 20 | 77 | 59 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2 | — | 5 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 4 | ..... | ..... | ..... | ..... | ..... |
| 21 | 75 | 66 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | 3 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1 | ..... | ..... | ..... | ..... | ..... |
| 22 | 88 | 57 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1 | ..... | 2 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1 | ..... | ..... | ..... | ..... | ..... |
| 23 | 93 | 61 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | 1 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2 | ..... | ..... | ..... | ..... | ..... |
| 24 | 86 | 66 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2 | ..... | 3 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1 | b | ..... | ..... | ..... | ..... |
| 25 | 85 | 64 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | 3 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | — | 0 | ..... | ..... | ..... | ..... |
| 26 | 87 | 65 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | 3 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... |
| 27 | 89 | 66 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | 3 | 2 | b | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... |
| 28 | 87 | 60 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | — | ..... | 3 | 2 | 0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | ..... | ..... | ..... | ..... |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | 88 | 62 | | | | | | | | | | | 4 | 2 | 0 | | | | | | | | | | | | | 0 | | | | |
| 30 | 91 | 63 | | | | | | | | | | | 3 | 1 | 0 | | | | | | | | | | | | | 0 | | | | |
| 31 | 91 | 60 | | | | | | | | | | | 4 | 0 | 0 | | | | | | | | | | | | | 2 | b | | | |
| Aug. 1 | 86 | 54 | | | | | | | | | | | 1 | 1 | 0 | | | | | | | | | | | | | 0 | 0 | | | |
| 2 | 93 | 53 | | | | | | | | | | | — | — | 0 | | | | | | | | | | | | | — | 0 | | | |
| 3 | 93 | 55 | | | | | | | | | | | | | 0 | | | | | | | | | | | | | | 0 | | | |
| 4 | 93 | 64 | | | | | | | | | | | | | 3 | b | | | | | | | | | | | | | 0 | | | |
| 5 | 82 | 67 | | | | | | | | | | | | | 6 | 0 | | | | | | | | | | | | | 0 | | | |
| 6 | 86 | 58 | | | | | | | | | | | | | | 0 | | | | | | | | | | | | | 0 | | | |
| 7 | 79 | 69 | | | | | | | | | | | | | 4 | 0 | | | | | | | | | | | | | 0 | | | |
| 8 | 75 | 55 | | | | | | | | | | | | | 3 | 0 | | | | | | | | | | | | | 0 | | | |
| 9 | 81 | 50 | | | | | | | | | | | | | 2 | 0 | | | | | | | | | | | | | 0 | | | |
| 10 | 82 | 54 | | | | | | | | | | | | | | 0 | | | | | | | | | | | | | 3 | | | |
| 11 | 88 | 55 | | | | | | | | | | | | | 3 | 0 | | | | | | | | | | | | | 3 | | | |
| 12 | 90 | 69 | | | | | | | | | | | | | 6 | 3 | b | | | | | | | | | | | | 2 | | | |
| 13 | 80 | 67 | | | | | | | | | | | | | | 3 | 0 | | | | | | | | | | | | | | | |
| 14 | 90 | 60 | | | | | | | | | | | | | 2 | 4 | 0 | | | | | | | | | | | | 0 | | | |
| 15 | 89 | 61 | | | | | | | | | | | | | 2 | 1 | 0 | | | | | | | | | | | | 3 | | | |
| 16 | 95 | 65 | | | | | | | | | | | | | 2 | 6 | 0 | | | | | | | | | | | | 2 | | | |
| 17 | 93 | 67 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | | | | | |
| 18 | 85 | 58 | | | | | | | | | | | | | — | 3 | 2 | b | | | | | | | | | | | 5 | | | |
| 19 | 95 | 52 | | | | | | | | | | | | | | 2 | 1 | 0 | | | | | | | | | | | 1 | | | |
| 20 | 77 | 56 | | | | | | | | | | | | | | 3 | 3 | 0 | | | | | | | | | | | 1 | | | |
| 21 | 86 | 47 | | | | | | | | | | | | | | 0 | 3 | 0 | | | | | | | | | | | 0 | | | |
| 22 | 86 | 60 | | | | | | | | | | | | | | 4 | 3 | 0 | | | | | | | | | | | 1 | | | |
| 23 | 83 | 53 | | | | | | | | | | | | | | 0 | 1 | 0 | | | | | | | | | | | 0 | | | |
| 24 | 80 | 50 | | | | | | | | | | | | | | 2 | 2 | 0 | | | | | | | | | | | 2 | | | |
| 25 | 83 | 53 | | | | | | | | | | | | | | — | 1 | 0 | | | | | | | | | | | 1 | | | |
| 26 | 81 | 54 | | | | | | | | | | | | | | | 0 | 0 | | | | | | | | | | | 1 | | | |
| 27 | 82 | 51 | | | | | | | | | | | | | | | — | 0 | | | | | | | | | | | 2 | b | | |
| 28 | 84 | 45 | | | | | | | | | | | | | | | | 0 | | | | | | | | | | | 0 | 0 | | |
| 29 | 93 | 51 | | | | | | | | | | | | | | | | 0 | | | | | | | | | | | 0 | 0 | | |
| 30 | 93 | 62 | | | | | | | | | | | | | | | | 0 | | | | | | | | | | | — | 0 | | |
| 31 | 95 | 54 | | | | | | | | | | | | | | | | 2 | b | | | | | | | | | | | 0 | | |
| Sept. 1 | 90 | 56 | | | | | | | | | | | | | | | | 3 | 0 | | | | | | | | | | | 0 | | |
| 2 | 77 | 46 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | 0 | | |
| 3 | 78 | 37 | | | | | | | | | | | | | | | | | 0 | | | | | | | | | | | 0 | | |
| 4 | 81 | 48 | | | | | | | | | | | | | | | | 0 | 0 | | | | | | | | | | | 0 | | |
| 5 | 86 | 50 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | 0 | | |
| 6 | 89 | 53 | | | | | | | | | | | | | | | | 4 | 0 | | | | | | | | | | | 0 | | |
| 7 | 74 | 46 | | | | | | | | | | | | | | | | | 0 | | | | | | | | | | | 0 | | |
| 8 | 82 | 40 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | 2 | | |
| 9 | 90 | 44 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | 1 | | |
| 10 | 93 | 50 | | | | | | | | | | | | | | | | 1 | 3 | b | | | | | | | | | | 2 | | |
| 11 | 94 | 51 | | | | | | | | | | | | | | | | — | 3 | 0 | | | | | | | | | | 2 | | |
| 12 | 94 | 54 | | | | | | | | | | | | | | | | | 2 | 0 | | | | | | | | | | 2 | | |
| 13 | 89 | 57 | | | | | | | | | | | | | | | | | 2 | 0 | | | | | | | | | | 2 | | |
| 14 | 84 | 49 | | | | | | | | | | | | | | | | | 3 | 0 | | | | | | | | | | 2 | | |
| 15 | 84 | 56 | | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | 1 | | |
| 16 | 85 | 52 | | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | 4 | | |
| 17 | 87 | 50 | | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | 2 | | |
| 18 | 91 | 48 | | | | | | | | | | | | | | | | | 5 | 0 | | | | | | | | | | 4 | | |
| 19 | 93 | 50 | | | | | | | | | | | | | | | | | | 3 | b | | | | | | | | | | | |

*First and last born generation series from an individual that hatched from the egg Mar. 27, 1908. Richmond, Ind.*—Continued.

| Date (1908). | Temperature. Maximum. | Temperature. Minimum. | First-born: First generation. | Second generation. | Third generation. | Fourth generation. | Fifth generation. | Sixth generation. | Seventh generation. | Eighth generation. | Ninth generation. | Tenth generation. | Eleventh generation. | Twelfth generation. | Thirteenth generation. | Fourteenth generation. | Fifteenth generation | Sixteenth generation. | Seventeenth generation. | Eighteenth generation. | Nineteenth generation. | Twentieth generation. | Twenty-first generation. | Last-born: Second generation. | Third generation. | Fourth generation. | Fifth generation. | Sixth generation. | Seventh generation. | Eighth generation. | Ninth generation. | Tenth generation. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | °F. | °F. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| June 22 | 91 | 64 | | | 0 | 0 | | 5 | 6 | 0 | | | | | | | | | | | | | | | 5 | | | | | | | |
| 23 | 93 | 68 | | | 0 | 0 | | 3 | 4 | 0 | | | | | | | | | | | | | | | 3 | | | | | | | |
| 24 | 94 | 67 | | | 0 | 0 | | 4 | 8 | 0 | | | | | | | | | | | | | | | 5 | | | | | | | |
| 25 | 79 | 52 | | | — | 0 | | | | 0 | | | | | | | | | | | | | | | | b | | | | | | |
| 26 | 79 | 49 | | | | 0 | | 2 | 7 | 4 | b | | | | | | | | | | | | | | 0 | 0 | | | | | | |
| 27 | 88 | 48 | | | | — | | | | 1 | 0 | | | | | | | | | | | | | | — | 0 | | | | | | |
| 28 | 89 | 52 | | | | | | — | 4 | 4 | 0 | | | | | | | | | | | | | | | 0 | | | | | | |
| 29 | 81 | 60 | | | | | | | 4 | 8 | 0 | | | | | | | | | | | | | | | 0 | | | | | | |
| 30 | 82 | 54 | | | | | | | | | 0 | | | | | | | | | | | | | | | 0 | | | | | | |
| July 1 | 89 | 52 | | | | | | | 4 | 4 | 0 | | | | | | | | | | | | | | | 0 | | | | | | |
| 2 | 89 | 57 | | | | | | | 4 | 3 | 0 | | | | | | | | | | | | | | | 0 | | | | | | |
| 3 | 82 | 64 | | | | | | | | 1 | 2 | b | | | | | | | | | | | | | | 0 | | | | | | |
| 4 | 82 | 66 | | | | | | | 1 | — | 3 | 0 | | | | | | | | | | | | | | 2 | | | | | | |
| 5 | 88 | 60 | | | | | | | 4 | | 3 | 0 | | | | | | | | | | | | | | 2 | | | | | | |
| 6 | 91 | 66 | | | | | | | 1 | | 3 | 0 | | | | | | | | | | | | | | 2 | | | | | | |
| 7 | 80 | 64 | | | | | | | 2 | | 8 | 0 | | | | | | | | | | | | | | 3 | | | | | | |
| 8 | 78 | 48 | | | | | | | 0 | | 5 | 0 | | | | | | | | | | | | | | 3 | | | | | | |
| 9 | 84 | 47 | | | | | | | — | | 5 | 0 | | | | | | | | | | | | | | 0 | | | | | | |
| 10 | 88 | 51 | | | | | | | | | 5 | 0 | | | | | | | | | | | | | | 2 | b | | | | | |
| 11 | 91 | 54 | | | | | | | | | 4 | 0 | | | | | | | | | | | | | | 0 | 0 | | | | | |
| 12 | 95 | 67 | | | | | | | | | 3 | 2 | b | | | | | | | | | | | | | 0 | 0 | | | | | |
| 13 | 92 | 63 | | | | | | | | | | 2 | 0 | | | | | | | | | | | | | — | 0 | | | | | |
| 14 | 86 | 65 | | | | | | | | | 3 | 3 | 0 | | | | | | | | | | | | | | 0 | | | | | |
| 15 | 79 | 57 | | | | | | | | | 3 | 4 | 0 | | | | | | | | | | | | | | 0 | | | | | |
| 16 | 87 | 54 | | | | | | | | | 3 | 1 | 0 | | | | | | | | | | | | | | 0 | | | | | |
| 17 | 90 | 66 | | | | | | | | | | | 0 | | | | | | | | | | | | | | 0 | | | | | |
| 18 | 84 | 71 | | | | | | | | | 6 | 2 | 3 | b | | | | | | | | | | | | | 0 | | | | | |
| 19 | 80 | 60 | | | | | | | | | | | 0 | 0 | | | | | | | | | | | | | 3 | | | | | |
| 20 | 77 | 59 | | | | | | | | | 2 | — | 5 | 0 | | | | | | | | | | | | | 4 | | | | | |
| 21 | 75 | 66 | | | | | | | | | 0 | | 3 | 0 | | | | | | | | | | | | | 1 | | | | | |
| 22 | 88 | 57 | | | | | | | | | 1 | | 2 | 0 | | | | | | | | | | | | | 1 | | | | | |
| 23 | 93 | 61 | | | | | | | | | 0 | | 1 | 0 | | | | | | | | | | | | | 2 | | | | | |
| 24 | 86 | 66 | | | | | | | | | 2 | | 3 | 0 | | | | | | | | | | | | | 1 | b | | | | |
| 25 | 85 | 64 | | | | | | | | | 0 | | 3 | 0 | | | | | | | | | | | | | — | 0 | | | | |
| 26 | 87 | 65 | | | | | | | | | 0 | | 3 | 0 | | | | | | | | | | | | | | 0 | | | | |
| 27 | 89 | 66 | | | | | | | | | 0 | | 3 | 2 | b | | | | | | | | | | | | | 0 | | | | |
| 28 | 87 | 60 | | | | | | | | | — | | 3 | 2 | 0 | | | | | | | | | | | | | 0 | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 29 | 88 | 62 | | | | | | | | | | | 4 | 2 | 0 | | | | | | | | | | | | | | 0 | | | | |
| | 30 | 91 | 63 | | | | | | | | | | | 3 | 1 | 0 | | | | | | | | | | | | | | 0 | | | | |
| | 31 | 91 | 60 | | | | | | | | | | | 4 | 0 | 0 | | | | | | | | | | | | | | 2 | b | | | |
| Aug. | 1 | 86 | 54 | | | | | | | | | | | 1 | 1 | 0 | | | | | | | | | | | | | | 0 | 0 | | | |
| | 2 | 93 | 53 | | | | | | | | | | | — | — | 0 | | | | | | | | | | | | | | — | 0 | | | |
| | 3 | 93 | 55 | | | | | | | | | | | | | 0 | | | | | | | | | | | | | | | 0 | | | |
| | 4 | 93 | 64 | | | | | | | | | | | | | 3 | b | | | | | | | | | | | | | | 0 | | | |
| | 5 | 82 | 67 | | | | | | | | | | | | | 6 | 0 | | | | | | | | | | | | | | 0 | | | |
| | 6 | 86 | 58 | | | | | | | | | | | | | | 0 | | | | | | | | | | | | | | 0 | | | |
| | 7 | 79 | 69 | | | | | | | | | | | | | 4 | 0 | | | | | | | | | | | | | | 0 | | | |
| | 8 | 75 | 55 | | | | | | | | | | | | | 3 | 0 | | | | | | | | | | | | | | 0 | | | |
| | 9 | 81 | 50 | | | | | | | | | | | | | 2 | 0 | | | | | | | | | | | | | | 0 | | | |
| | 10 | 82 | 54 | | | | | | | | | | | | | | 0 | | | | | | | | | | | | | | 3 | | | |
| | 11 | 88 | 55 | | | | | | | | | | | | | 3 | 0 | | | | | | | | | | | | | | 3 | | | |
| | 12 | 90 | 69 | | | | | | | | | | | | | 6 | 3 | b | | | | | | | | | | | | | 2 | | | |
| | 13 | 80 | 67 | | | | | | | | | | | | | | 3 | 0 | | | | | | | | | | | | | | | | |
| | 14 | 90 | 60 | | | | | | | | | | | | | 2 | 4 | 0 | | | | | | | | | | | | | 0 | | | |
| | 15 | 89 | 61 | | | | | | | | | | | | | 2 | 1 | 0 | | | | | | | | | | | | | 3 | | | |
| | 16 | 95 | 65 | | | | | | | | | | | | | 2 | 6 | 0 | | | | | | | | | | | | | 2 | | | |
| | 17 | 93 | 67 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | | | | | | |
| | 18 | 85 | 58 | | | | | | | | | | | | | — | 3 | 2 | b | | | | | | | | | | | | 5 | | | |
| | 19 | 95 | 52 | | | | | | | | | | | | | | 2 | 1 | 0 | | | | | | | | | | | | 1 | | | |
| | 20 | 77 | 56 | | | | | | | | | | | | | | 3 | 3 | 0 | | | | | | | | | | | | 1 | | | |
| | 21 | 86 | 47 | | | | | | | | | | | | | | 0 | 3 | 0 | | | | | | | | | | | | 0 | | | |
| | 22 | 86 | 60 | | | | | | | | | | | | | | 4 | 3 | 0 | | | | | | | | | | | | 1 | | | |
| | 23 | 83 | 53 | | | | | | | | | | | | | | 0 | 1 | 0 | | | | | | | | | | | | 0 | | | |
| | 24 | 80 | 50 | | | | | | | | | | | | | | 2 | 2 | 0 | | | | | | | | | | | | 2 | | | |
| | 25 | 83 | 53 | | | | | | | | | | | | | | — | 1 | 0 | | | | | | | | | | | | 1 | | | |
| | 26 | 81 | 54 | | | | | | | | | | | | | | | 0 | 0 | | | | | | | | | | | | 1 | | | |
| | 27 | 82 | 51 | | | | | | | | | | | | | | | — | 0 | | | | | | | | | | | | 2 | b | | |
| | 28 | 84 | 45 | | | | | | | | | | | | | | | | 0 | | | | | | | | | | | | 0 | 0 | | |
| | 29 | 93 | 51 | | | | | | | | | | | | | | | | 0 | | | | | | | | | | | | 0 | 0 | | |
| | 30 | 93 | 62 | | | | | | | | | | | | | | | | 0 | | | | | | | | | | | | — | 0 | | |
| | 31 | 95 | 54 | | | | | | | | | | | | | | | | 2 | b | | | | | | | | | | | | 0 | | |
| Sept. | 1 | 90 | 56 | | | | | | | | | | | | | | | | 3 | 0 | | | | | | | | | | | | 0 | | |
| | 2 | 77 | 46 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | | 0 | | |
| | 3 | 73 | 37 | | | | | | | | | | | | | | | | | 0 | | | | | | | | | | | | 0 | | |
| | 4 | 81 | 48 | | | | | | | | | | | | | | | | 0 | 0 | | | | | | | | | | | | 0 | | |
| | 5 | 86 | 50 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | | 0 | | |
| | 6 | 89 | 53 | | | | | | | | | | | | | | | | 4 | 0 | | | | | | | | | | | | 0 | | |
| | 7 | 74 | 46 | | | | | | | | | | | | | | | | | 0 | | | | | | | | | | | | 0 | | |
| | 8 | 82 | 40 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | | 2 | | |
| | 9 | 90 | 44 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | | 1 | | |
| | 10 | 93 | 50 | | | | | | | | | | | | | | | | 1 | 3 | b | | | | | | | | | | | 2 | | |
| | 11 | 94 | 51 | | | | | | | | | | | | | | | | — | 3 | 0 | | | | | | | | | | | 2 | | |
| | 12 | 94 | 54 | | | | | | | | | | | | | | | | | 2 | 0 | | | | | | | | | | | 2 | | |
| | 13 | 89 | 57 | | | | | | | | | | | | | | | | | 2 | 0 | | | | | | | | | | | 2 | | |
| | 14 | 84 | 49 | | | | | | | | | | | | | | | | | 3 | 0 | | | | | | | | | | | 2 | | |
| | 15 | 84 | 56 | | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | 1 | | |
| | 16 | 85 | 52 | | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | 4 | | |
| | 17 | 87 | 50 | | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | 2 | | |
| | 18 | 91 | 48 | | | | | | | | | | | | | | | | | 5 | 0 | | | | | | | | | | | 4 | | |
| | 19 | 93 | 50 | | | | | | | | | | | | | | | | | | 3 | b | | | | | | | | | | | | |

*First and last born generation series from an individual that hatched from the egg Mar. 27, 1908. Richmond, Ind.*—Continued.

| Date (1908). | Temperature. Maximum. | Temperature. Minimum. | First-born generation series. First generation. | Second generation. | Third generation. | Fourth generation. | Fifth generation. | Sixth generation. | Seventh generation. | Eighth generation. | Ninth generation. | Tenth generation. | Eleventh generation. | Twelfth generation. | Thirteenth generation. | Fourteenth generation. | Fifteenth generation. | Sixteenth generation. | Seventeenth generation. | Eighteenth generation. | Nineteenth generation. | Twentieth generation. | Twenty-first generation. | Last-born generation series. Second generation. | Third generation. | Fourth generation. | Fifth generation. | Sixth generation. | Seventh generation. | Eighth generation. | Ninth generation. | Tenth generation. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | °F. | °F. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 20 | 95 | 50 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3 | 3 | 0 | .... | .... | .... | .... | .... | .... | .... | .... | 5 | .... | .... |
| 21 | 95 | 51 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | | | 0 | .... | .... | .... | .... | .... | .... | .... | .... | | .... | .... |
| 22 | 91 | 51 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3 | 1 | 0 | .... | .... | .... | .... | .... | .... | .... | .... | 2 | .... | .... |
| 23 | 90 | 53 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | 3 | 0 | .... | .... | .... | .... | .... | .... | .... | .... | 1 | .... | .... |
| 24 | 93 | 53 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 3 | 0 | .... | .... | .... | .... | .... | .... | .... | .... | 3 | .... | .... |
| 25 | 92 | 51 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 4 | 0 | 0 | .... | .... | .... | .... | .... | .... | .... | .... | 2 | .... | .... |
| 26 | 90 | 57 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | | 1 | 0 | .... | .... | .... | .... | .... | .... | .... | .... | 2 | .... | .... |
| 27 | 87 | 54 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | | | 0 | .... | .... | .... | .... | .... | .... | .... | .... | 4 | *b* | .... |
| 28 | 76 | 44 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3 | 3 | 0 | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 29 | 53 | 34 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | | | 0 | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 30 | 74 | 33 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | | | 2 | *b* | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| Oct. 1 | 62 | 34 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | 2 | 1 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 2 | 57 | 25 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 1 | 0 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 3 | 69 | 27 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 1 | 0 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 4 | 79 | 27 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | 0 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 5 | 86 | 34 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | — | 1 | 2 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 6 | 83 | 39 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | 0 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 7 | 76 | 42 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 1 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 8 | 60 | 41 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2 | 0 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 9 | 60 | 37 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | | 0 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 10 | 65 | 45 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 1 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 11 | 51 | 39 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | 0 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 12 | 59 | 25 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 13 | 73 | 26 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | — | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 14 | 74 | 38 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 15 | 79 | 46 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3 | .... | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 16 | 78 | 42 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | | .... | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... |
| 17 | 81 | 39 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2 | .... | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | 3 | *b* |
| 18 | 84 | 46 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | — | .... | 0 | .... | .... | .... | .... | .... | .... | .... | 0 | | 0 |
| 19 | 75 | 47 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2 | *b* | .... | .... | .... | .... | .... | .... | 0 | 6 | 0 |
| 20 | 77 | 47 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | 0 | .... | .... | .... | .... | .... | .... | 0 | | 0 |
| 21 | 79 | 45 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | 0 | .... | .... | .... | .... | .... | .... | 0 | 3 | 0 |
| 22 | 72 | 40 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | 0 | .... | .... | .... | .... | .... | .... | 0 | 1 | 0 |
| 23 | 66 | 50 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | 0 | .... | .... | .... | .... | .... | .... | 0 | 2 | 0 |
| 24 | 68 | 55 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3 | 0 | .... | .... | .... | .... | .... | .... | 0 | 2 | 0 |
| 25 | 59 | 32 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | .... | .... | .... | .... | .... | .... | 0 | 0 | 0 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 62 | 32 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | 0 | ... | ... | ... | ... | ... | ... | — | 0 | 0 |
| 27 | 56 | 34 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 0 | ... | ... | ... | ... | ... | ... | ... | 2 | 0 |
| 28 | 55 | 32 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 | 0 |
| 29 | 56 | 29 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 | 0 |
| 30 | 50 | 26 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 | 0 |
| 31 | 47 | 17 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 | 0 |
| Nov. 1 | 49 | 21 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 2 | 0 | ... | ... | ... | ... | ... | ... | ... | 0 | 0 |
| 2 | 55 | 35 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | — | 0 | ... | ... | ... | ... | ... | ... | ... | 0 | 0 |
| 3 | 66 | 37 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | 0 | 0 |
| 4 | 62 | 32 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | 0 | 0 |
| 5 | 40 | 9 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | 0 | 0 |
| 6 | 61 | 29 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | — | 0 |
| 7 | 58 | 24 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | 0 |
| 8 | 57 | 30 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | 0 |
| 9 | 52 | 31 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | [1] |
| 10 | 43 | 32 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 11 | 43 | 30 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 12 | 38 | 13 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 13 | 33 | 11 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 14 | 29 | 18 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 15 | 39 | 24 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 16 | 35 | 24 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 17 | 52 | 13 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 18 | 58 | 43 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 19 | 60 | 27 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 20 | 67 | 35 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 21 | 56 | 22 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 22 | 66 | 35 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 23 | 66 | 47 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | | | | | | | | | | | | | | | | | | | | | | [1] | | | | | | | | | |

[1] Adult oviparous. ♀

### STEM MOTHERS.

At both Richmond and La Fayette, Ind., the eggs begin to hatch the latter part of March and continue until about April 10. The first generation, or stem mothers, differs from the next generation slightly in coloration, and there are besides some slight structural differences. The measurements of the body are not included in the following description, as the specimens are mounted in balsam.

### DESCRIPTION OF THE DIFFERENT INSTARS.

*First instar.*—Before first molt: General color, very dark Nile green; head, beak, antennæ, legs, and cornicles very dark gray; tips of the antennæ, the tarsi, and the eyes black. Antennæ 4-segmented.

Measurements of antennal joints (average from 2 specimens): I, 0.034 mm.; II, 0.034 mm.; III, 0.093 mm.; IV, base, 0.046 mm.; IV, filament, 0.114 mm.; total length, 0.321 mm.

*Second instar.*—Before second molt: General coloration of head and body lighter than in the preceding stage, otherwise the coloration the same. Antennæ 5-segmented.

Measurements of antennal joints (average from 3 specimens): I, 0.045 mm.; II, 0.039 mm.; III, 0.127 mm.; IV, 0.082 mm.; V, base, 0.066 mm.; V, filament, 0.161 mm.; total length, 0.520 mm.

*Third instar.*—Before third molt: The color of the body now varies from pale green to deep apple green; head concolorous with body; legs slightly lighter; eyes, tip of beak, tip of cornicles, articulation of femora, and tibiæ black; distal two-thirds of antennæ black; basal portion greenish gray. Antennæ 5-jointed.

Measurements of antennal joints (average from 4 specimens): I, 0.050 mm.; II, 0.045 mm.; III, 0.152 mm.; IV, 0.093 mm.; V, base, 0.072 mm.; V, filament, 0.174 mm.; total length, 0.586 mm.

*Fourth instar.*—Before fourth molt: General coloration variable, though about the same as in third instar, with the exception that the eyes of the young begin to show through the body wall; eyes and tip of beak black; legs greenish gray, the articulation of femora and tibiæ and the distal portion of tibiæ very dark, and tarsi black; cauda lighter than the body, as is sometimes also the head; the two distal segments and distal portion of third segment of antennæ black, gradually shading off until at the base they are concolorous with the head; cornicles black at tips, shading off into pale grayish green at base. Antennæ 5-jointed; sometimes, however, there are 6 distinct joints.

Measurements of antennal joints (average from 4 specimens): I, 0.065 mm.; II, 0.051 mm.; III, 0.194 mm.; IV, 0.119 mm.; V, base, 0.088 mm.; V, filament, 0.196 mm.; total length, 0.713 mm.

*Fifth instar.*—In the adult stage the color varies from a clay yellow to greenish yellow and deep apple green; there is no central dorsal stripe; the eyes of the young show through the body walls. In some of the greener specimens the head is slightly lighter and in some of the lighter colored specimens the head is slightly darker than the body; eyes and tip of beak black; legs pale greenish gray, the articulation of femora and tibiæ and the distal third of tibiæ quite dark; tarsi black; cauda in yellow specimens with a yellowish tint and in the deep green specimens somewhat grayish, shape and length same as in summer form; cornicles concolorous with body except the distal third, which is black, shape and length same as in summer form; three distal segments of antennæ and distal half of fourth black, the basal joints concolorous with the head. Antennæ 6-segmented, though two specimens were found in which one antenna of each was only 5-segmented.

Measurements of antennal joints (average from 16 specimens): I, 0.066 mm.; II, 0.049 mm.; III, 0.226 mm.; IV, 0.140 mm.; V, 0.152 mm.; VI, base, 0.091 mm.; VI, filament, 0.225 mm.; total length, 0.951 mm. They are slightly pruinose in each stage.

The material from which these data were taken is mounted on slides and is in the collections of the Bureau of Entomology, bearing Webster number 5151.

The first generation, or stem mothers, is always wingless. All of the following generations differ in color, more especially in the first and second instars. The adult stem mothers, so far as we have been able to learn, never have the darker green dorsal stripe. The antennæ are shorter throughout the different instars, and in the adult also, than in the summer forms.

FIG. 12.—The spring grain-aphis: Young, first instar. Enlarged; actual size, 0.75 mm. (Original.)

## DESCRIPTION OF THE SUMMER FORMS.

*First instar* (fig. 12).—Before first molt: General color very pale green, the thorax probably the palest; head pale green with a dusky tinge; eyes brownish black; tip of cornicles black, bases dusky; articulation of femora and tibiæ and distal portion of tibiæ dusky; tarsi black; two apical segments of antennæ black, remaining segments concolorous with head. Antennæ 4-segmented.

Measurements of antennal joints (average from 3 specimens): I, 0.032 mm.; II, 0.033 mm.; III, 0.118 mm.; IV, base, 0.049 mm.; IV, filament, 0.154 mm.; total length, 0.386 mm.

*Second instar* (fig. 13).—Before second molt: General color slightly paler now; head not dusky; eyes same as in preceding stage; legs with a more greenish tinge now, otherwise same as in previous stage; the two basal joints and the proximal portion of the third joint of antennæ concolorous with head, other portion black. Antennæ 5-jointed.

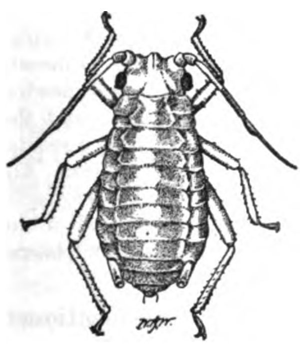

FIG. 13.—The spring grain-aphis: Young, second instar. Enlarged; actual size, 0.922 mm. (Original.)

Measurements of antennal joints (average from 2 specimens): I, 0.041 mm.; II, 0.035 mm.; III, 0.106 mm.; IV, 0.075 mm.; V, base, 0.062 mm.; V, filament, 0.204 mm.; total length, 0.523 mm.

*Third instar*.—Before third molt: Coloration practically same as in second instar; eyes almost black; bases of cornicles paler than abdomen. Antennæ 5-jointed.

Measurements of antennal joints (average from 2 specimens): I, 0.056 mm.; II, 0.045 mm.; III, 0.172 mm.; IV, 0.099 mm.; V, base, 0.076 mm.; V, filament, 0.259 mm.; total length, 0.707 mm.

*Fourth instar*.—Before fourth molt: General color deeper green now, very close to apple green; dorsal stripe apparent in this stage at times, eyes of young showing through body wall at this time, head a shade lighter than body and sometimes seeming to be tinged with yellow; eyes brownish black; beak black at tip; legs more of a yellowish green now, the articulation of femora and tibiæ and the distal portion of the tibiæ dusky; tarsi black; the two apical segments of antennæ black, next much lighter, third slightly dusky, and the two basal segments concolorous with head. Antennæ 5-segmented, although sometimes they appear to have 6 segments.

Measurements of antennal joints (average from 2 specimens): I, 0.060 mm.; II, 0.045 mm.; III, 0.272 mm. IV, 0.120 mm.; V, base, 0.086 mm.; V, filament, 0.282 mm.; total length, 0.865 mm.

All of the above stages slightly pruinose.

The following is the description of the adult, summer forms, as given by Mr. Pergande:[1]

*Apterous female* [fig. 8].—Length 1-1.8 mm.: color yellowish green and slightly pruinose, the median line darker green, the head and prothorax somewhat paler than the rest of the body. Eyes black. Antennæ black, the two basal joints and more or less of the third joint at base yellowish. Legs yellowish, the tibiæ brownish toward the apex, tarsi black. Tail dusky. The general color of the larvæ and pupæ is like that of the apterous female. Wing pads of pupa dusky to black. Antennæ slender and about one-half the length of the body. Nectaries slightly tapering, reaching to or slightly beyond the end of the body. Tail slender, somewhat constricted about the middle, and about two-thirds the length of the nectaries. There is a distinct fleshy tubercle each side of the prothorax and similar tubercles along both sides of the abdomen.

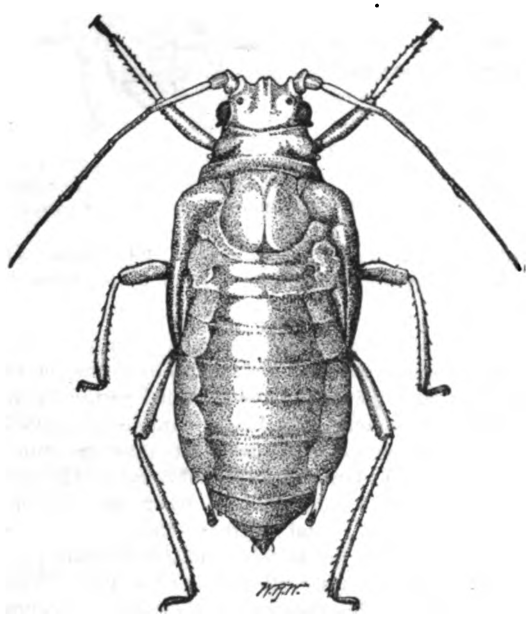

FIG. 14.—The spring grain-aphis: Pupa of winged viviparous female. Enlarged; actual size, 1.875 mm. (Original.)

*Migratory female* [fig. 7].—Expanse of wings 5–7 mm.; length of body 1.5–2 mm. General coloration of the abdomen as in the apterous forms; head brownish yellow; the eyes brown; antennæ, thoracic lobes, the posterior margin of the scutellum, and the sternal plate black; the two basal joints of the antennæ yellowish green; legs yellow, the femora more or less dusky, the posterior pair darkest; apex of tibiæ and the tarsi black; nectaries and tail yellowish, the latter changing gradually to dusky or black toward the end; wings transparent; costa and subcosta yellow; the stigma somewhat paler, its inner edge and the veins black. Third discoidal vein with but one fork. Antennæ long and slender, reaching nearly to the end of the body, the third joint provided with 3 to 7 sensoria. Nectaries, tail, and lateral tubercles, as in the apterous females.

Besides the sensoria on the third segment of the antennæ mentioned in the above description, there are from 1 to 2 on the fourth, 1 near the apex of fifth, and several, more or less distinct, on the base of the sixth.

Measurements of antennal joints (average from 8 specimens): I, 0.082 mm.; II, 0.059 mm.; III, 0.300 mm.; IV, 0.223 mm.; V, 0.215 mm.; VI, base, 0.110 mm.; VI, filament, 0.395 mm.; total length, 1.384 mm.

To this description we add:

*Wingless female* (fig. 8).—Coloration for this stage varying from a very pale green with a slight tinge of yellow to a deep apple-green. The dorsal stripe is not always

[1] Bulletin 38, Div. Ent., U. S. Dept. Agr., p. 18, 1902.

present. The size varies greatly in nearly all forms, wingless viviparous females varying from 1.5 mm. to over 2 mm.

Measurements of antennal joints (average for 8 specimens): I, 0.069 mm.; II, 0.045 mm.; III, 0.210 mm.; IV, 0.135 mm.; V, 0.140 mm.; VI, base, 0.089 mm. VI, filament, 0.305 mm.; total length, 0.993 mm.

*Pupæ* (fig. 14).—Measurements of antennal joints (average from 8 specimens): I, 0.064 mm.; II, 0.056 mm.; III, 0.186 mm.; IV, 0.127 mm.; V, 0.134 mm.; VI, base, 0.090 mm.; VI, filament, 0.270 mm.; total length, 0.927 mm.

*Winged viviparous female* (fig. 7).—Measurements of antennal joints (average from 8 specimens): I, 0.082 mm.; II, 0.059 mm.; III, 0.300 mm.; IV, 0.223 mm.; V, 0.215 mm.; VI, base, 0.110 mm.; VI, filament, 0.395 mm.; total length, 1.384 mm.

## MOLTING.

The time required for molting, from beginning to completion, is 30 minutes. The first indication is restlessness; the antennæ are waved continuously and the legs move jerkily. This period of restlessness continues for 10 minutes, after which the antennæ are allowed to come to rest close down upon the dorsum. A few minutes later the tip of the abdomen will appear transparent and baggy, due to the old skin having slipped backward; the head and eyes are now being freed. It appears that the skin first ruptures in the cephalic region and only splits a part of the length of the dorsum, the insect gradually working its way out from this extremity. After the head, the antennæ are the first to be liberated, then each pair of legs in succession, and after all of the appendages have been freed the insect has still to struggle somewhat to free its abdomen. These observations were made on individuals casting the third or fourth molt.

## NUMBER OF MOLTS.

Quite a number of observations were made on the number of molts and the period between the same, it being learned that stem mothers, the summer forms, and the sexes molt 4 times only.

To facilitate careful and accurate observations upon the number of molts, a young wheat plant was potted in a 5-inch flowerpot. A circle of black paper was cut small enough to fit down in the top of the pot. A small hole was then cut in the center and the paper disk was then fitted closely down about the base of the plant. After the paper was in place the space immediately around the plant was filled in with absorbent cotton made black with waterproof ink. Then a young Toxoptera that had just been born was placed on the plant inclosed by a clean lantern globe, with a piece of new cheesecloth firmly secured over the top to prevent the grayish cast skins from being overlooked. Each cast skin was removed as soon as the molt was completed, and a record made so that it could not possibly be counted a second time. All observations recorded in the notes on molting were made in this manner.

During the summer of 1907, at Richmond, Ind., careful observations were made on 7 individuals of the summer forms, and in the fall Mr. R. A. Vickery, of this bureau, made observations on 6 individuals, 3 of which proved to be males and 3 oviparous females. In each case there were 4 molts. In the spring of 1908, 4 stem mothers were found to molt 4 times only. In the spring of 1909 at Lafayette, Ind., 1 stem mother was found to molt 4 times. Later on in the summer, Mr. T. H. Parks, of this bureau, ran a series of experiments with the summer forms and, of the 30 individuals under observation, some of which were winged, he found that all without exception molted 4 times. In the fall of 1910 several additional oviparous females were found to molt 4 times only. This makes a total of over 50 specimens that came under our observation, under conditions that would absolutely preclude error, and there was not a single exception—all molting 4 times.

As it was found that the period between molts varied, experiments were begun in the summer of 1907 at Richmond, Ind., in order to learn how great the variation was when each individual was subjected to the same conditions.[1] This experiment was carried on indoors and all individuals were subjected to the same conditions. Table II will show the variations.

TABLE II.—*Variation in the duration of the different instars in Toxoptera graminum.*

| Individual. | From time of birth to first molt. | From first molt to second molt. | From second molt to third molt. | From third molt to fourth molt. |
|---|---|---|---|---|
| | *H. m.* | *H. m.* | *H. m.* | *H. m.* |
| A | 38 35 | 28 29 | 31 37 | 39 40 |
| B | 40 15 | 29 15 | 34 36 | 34 37 |
| C | 50 20 | 26 40 | 35 48 | 40 22 |
| D | 45 | 54 | 40 | 64 |
| E | 44 30 | 32 35 | 36 50 | 39 37 |

There is also considerable variation in the time from birth of individuals to the fourth molt and the appearance of the first young, as will be seen from Table III. Individuals in Table III are the same as in Table II, with the addition of "F" and "1*b*[3]."

TABLE III.—*Variation in the time from birth of individuals to fourth molt and appearance of first young in Toxoptera graminum.*

| Individual. | From time of birth to fourth molt. | | From time of birth until first young appear. | |
|---|---|---|---|---|
| | *Hours.* | *Days.* | *H. m.* | *Days.* |
| A | 143–144 | 5.9 | 144 35 | 6.02 |
| B | 143 | 5.9 | 148 | 6.1 |
| C | 153 | 6.3 | 164 | 6.8 |
| D | 153 | 6.3 | 165 | 6.8 |
| E | 204 | 8.5 | 246 | 10.02 |
| F | 195 | 8.1 | 205 | 8.5 |
| 1*b*[3] | 170–175 | 7.1 | [2] 175 | 7.2 |

[1] Proc. Ent. Soc. Wash., vol. 10, Nos. 1-2, pp. 11-13, 1908.
[2] Approximate.

## BIRTH OF YOUNG.

In the fall of the year 1907 adult individuals of Toxoptera were brought from out of doors into a warm room, placed under a microscope, and observations made on the manner of birth of the young. The embryonic young within the body of the parent are inclosed within a thin, transparent, structureless membrane that corresponds to the vitelline membrane in the true egg. Normally, in warm temperatures, the young Toxoptera frees itself from this enveloping sac during birth. At a temperature of about 60° F. or below, the young are oftentimes dropped before they free themselves from the sac. In this latter case, upon landing upon the surface of the leaf they expand and contract gently until the sac is ruptured at the cephalic extremity and they are freed from their prison.

## NUMBER OF GENERATIONS PER YEAR.

During the summer of 1907, at Richmond, Ind., a study of the continuous generations of this species was begun and followed through until December 10, the sexual forms and eggs being secured from bluegrass in the fields in October. With some of the young that hatched from these eggs (stem mothers) March 27 five lines of continuous-generation studies were begun and continued until the appearance of the sexes and eggs in the fall. These eggs were carefully retained and taken to Lafayette, Ind., where, upon their hatching on the first day of the following April, two more lines of continuous-generation studies were begun and continued until ended by the appearance of the sexes and eggs in the fall of 1909, as was the case in 1908.

*Toxoptera graminum.* *Generation series showing daily reproduction, temperatures, etc. Observations made at Dallas, Tex., 1909, by T. D. Urbahns. Series begun with viviparous and ended with viviparous. No sexes.*

[*b*=born. —=died or disappeared.]

| Date. | Temperature. Maximum. | Temperature. Minimum. | First generation. | Second generation. | Third generation. | Fourth generation. | Fifth generation. | Sixth generation. | Seventh generation. | Eighth generation. | Ninth generation. | Tenth generation. | Eleventh generation. | Twelfth generation. | Thirteenth generation. | Fourteenth generation. | Fifteenth generation. | Sixteenth generation. | Seventeenth generation. | Eighteenth generation. | Nineteenth generation. | Twentieth generation. | Twenty-first generation. | Twenty-second generation. | Twenty-third generation. | Twenty-fourth generation. | Twenty-fifth generation. | Twenty-sixth generation. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1909. | °F. | °F. | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mar. 31 | | | *b* | | | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 1 | 67 | 42 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | 87 | 37 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 90 | 44 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | 84 | 56 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | 84 | 65 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | 83 | 86 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | 69 | 48 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 61 | 50 | 1 | *b* | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | 73 | 30 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 75 | 34 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | 76 | 51 | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | 80 | 60 | 4 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | 70 | 34 | 8 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | 75 | 44 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | 79 | 45 | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | 85 | 55 | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | 85 | 58 | 4 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | 87 | 64 | 4 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | 74 | 56 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 69 | 49 | 2 | 1 | *b* | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | 74 | 54 | 1 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | 64 | 51 | 1 | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | 65 | 41 | 1 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | 74 | 52 | 1 | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | 81 | 62 | 5 | 5 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | 75 | 64 | 8 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | 75 | 59 | 1 | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | 85 | 63 | 4 | 4 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | 98 | 70 | 4 | 4 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | 67 | 53 | 2 | 5 | 4 | *b* | | | | | | | | | | | | | | | | | | | | | | |
| May 1 | 68 | 35 | 0 | 0 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | |
| 2 | 68 | 35 | 0 | 1 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 87 | 55 | 1 | 4 | 6 | 0 | | | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 93 | 64 | 0 | 3 | 7 | 0 | | | | | | | | | | | | | | | | | | | | | | |
| 5 | 88 | 66 | 0 | 3 | 6 | 0 | | | | | | | | | | | | | | | | | | | | | | |
| 6 | 80 | 60 | 0 | 4 | 6 | 0 | | | | | | | | | | | | | | | | | | | | | | |
| 7 | 87 | 56 | 1 | 2 | 8 | 0 | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 89 | 69 | 0 | – | 7 | 2 | b | | | | | | | | | | | | | | | | | | | | | |
| 9 | 74 | 57 | – | | 6 | 4 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 10 | 78 | 41 | | | – | 4 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 11 | 80 | 44 | | | | 4 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 12 | 84 | 61 | | | | 5 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 13 | 87 | 64 | | | | 6 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 14 | 86 | 69 | | | | 4 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 15 | 85 | 67 | | | | 7 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 16 | 89 | 56 | | | | 4 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 17 | 93 | 67 | | | | 7 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 18 | 77 | 70 | | | | 3 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 19 | 87 | 56 | | | | 3 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 20 | 84 | 66 | | | | 5 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 21 | 84 | 58 | | | | 1 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 22 | 90 | 62 | | | | 0 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 23 | 91 | 68 | | | | 0 | 6 | b | | | | | | | | | | | | | | | | | | | | |
| 24 | 89 | 73 | | | | 0 | 5 | 0 | | | | | | | | | | | | | | | | | | | | |
| 25 | 89 | 65 | | | | 0 | 5 | 0 | | | | | | | | | | | | | | | | | | | | |
| 26 | 85 | 60 | | | | 0 | 4 | 0 | | | | | | | | | | | | | | | | | | | | |
| 27 | 95 | 65 | | | | 0 | 3 | 0 | | | | | | | | | | | | | | | | | | | | |
| 28 | 87 | 67 | | | | 0 | 7 | 0 | | | | | | | | | | | | | | | | | | | | |
| 29 | 89 | 70 | | | | 0 | 7 | 2 | b | | | | | | | | | | | | | | | | | | | |
| 30 | 85 | 73 | | | | 0 | 4 | 4 | 0 | | | | | | | | | | | | | | | | | | | |
| 31 | 89 | 54 | | | | 0 | 4 | 4 | 0 | | | | | | | | | | | | | | | | | | | |
| June 1 | 77 | 66 | | | | 0 | 3 | 4 | 0 | | | | | | | | | | | | | | | | | | | |
| 2 | 90 | 57 | | | | 0 | 5 | 3 | 0 | | | | | | | | | | | | | | | | | | | |
| 3 | 93 | 60 | | | | 0 | – | 4 | 0 | | | | | | | | | | | | | | | | | | | |
| 4 | 95 | 64 | | | | 0 | | 4 | 0 | | | | | | | | | | | | | | | | | | | |
| 5 | 98 | 59 | | | | 0 | | 4 | 0 | | | | | | | | | | | | | | | | | | | |
| 6 | 98 | 64 | | | | 0 | | 3 | 3 | b | | | | | | | | | | | | | | | | | | |
| 7 | 93 | 67 | | | | 0 | | 3 | 3 | 0 | | | | | | | | | | | | | | | | | | |
| 8 | 96 | 67 | | | | – | | 3 | 3 | 0 | | | | | | | | | | | | | | | | | | |
| 9 | 95 | 74 | | | | | | 3 | 3 | 0 | | | | | | | | | | | | | | | | | | |
| 10 | 93 | 65 | | | | | | 5 | 4 | 0 | | | | | | | | | | | | | | | | | | |
| 11 | 92 | 70 | | | | | | 4 | 5 | 0 | | | | | | | | | | | | | | | | | | |
| 12 | 92 | 69 | | | | | | 1 | 5 | 0 | | | | | | | | | | | | | | | | | | |
| 13 | 80 | 66 | | | | | | 1 | 4 | 3 | b | | | | | | | | | | | | | | | | | |
| 14 | 91 | 64 | | | | | | 0 | 4 | 3 | 0 | | | | | | | | | | | | | | | | | |
| 15 | 92 | 69 | | | | | | 0 | 4 | 4 | 0 | | | | | | | | | | | | | | | | | |
| 16 | 96 | 68 | | | | | | – | (1) | (1) | 0 | | | | | | | | | | | | | | | | | |
| 17 | 99 | 77 | | | | | | | (1) | (1) | 0 | | | | | | | | | | | | | | | | | |
| 18 | 93 | 69 | | | | | | | (1) | (1) | 0 | | | | | | | | | | | | | | | | | |
| 19 | 95 | 70 | | | | | | | (1) | (1) | 0 | | | | | | | | | | | | | | | | | |
| 20 | 96 | 71 | | | | | | | (1) | (1) | 0 | | | | | | | | | | | | | | | | | |
| 21 | 96 | 69 | | | | | | | (1) | (1) | 0 | | | | | | | | | | | | | | | | | |
| 22 | 91 | 73 | | | | | | | – | (1) | 5 | b | | | | | | | | | | | | | | | | |
| 23 | 91 | 67 | | | | | | | | (1) | (1) | 0 | | | | | | | | | | | | | | | | |

[1] No observations on these dates.

*Toxoptera graminum. Generation series showing daily reproduction, temperatures, etc. Observations made at Dallas, Tex., 1909, by T. D. Urbahns. Series begun with viviparous and ended with viviparous. No sexes*—Continued.

| Date. | Temperature. Maximum. | Temperature. Minimum. | First generation. | Second generation. | Third generation. | Fourth generation. | Fifth generation. | Sixth generation. | Seventh generation. | Eighth generation. | Ninth generation. | Tenth generation. | Eleventh generation. | Twelfth generation. | Thirteenth generation. | Fourteenth generation. | Fifteenth generation. | Sixteenth generation. | Seventeenth generation. | Eighteenth generation. | Nineteenth generation. | Twentieth generation. | Twenty-first generation. | Twenty-second generation. | Twenty-third generation. | Twenty-fourth generation. | Twenty-fifth generation. | Twenty-sixth generation. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1909. | °F. | °F. | | | | | | | | | | | | | | | | | | | | | | | | | | |
| June 24 | 92 | 74 | | | | | | | | (1) | (1) | 0 | | | | | | | | | | | | | | | | |
| 25 | 93 | 75 | | | | | | | | (1) | (1) | 0 | | | | | | | | | | | | | | | | |
| 26 | 87 | 75 | | | | | | | | (1) | (1) | 0 | | | | | | | | | | | | | | | | |
| 27 | 96 | 71 | | | | | | | | (1) | (1) | 0 | | | | | | | | | | | | | | | | |
| 28 | 98 | 76 | | | | | | | | (1) | (1) | 0 | | | | | | | | | | | | | | | | |
| 29 | 99 | 75 | | | | | | | | | | 2 | b | | | | | | | | | | | | | | | |
| 30 | 99 | 71 | | | | | | | | | | — | 0 | | | | | | | | | | | | | | | |
| July 1 | 99 | 72 | | | | | | | | | | | 0 | | | | | | | | | | | | | | | |
| 2 | 88 | 74 | | | | | | | | | | | 0 | | | | | | | | | | | | | | | |
| 3 | 100 | 72 | | | | | | | | | | | 0 | | | | | | | | | | | | | | | |
| 4 | 100 | 75 | | | | | | | | | | | 0 | | | | | | | | | | | | | | | |
| 5 | 96 | 75 | | | | | | | | | | | 0 | | | | | | | | | | | | | | | |
| 6 | 97 | 77 | | | | | | | | | | | 0 | | | | | | | | | | | | | | | |
| 7 | 99 | 75 | | | | | | | | | | | 2 | b | | | | | | | | | | | | | | |
| 8 | 99 | 77 | | | | | | | | | | | 2 | 0 | | | | | | | | | | | | | | |
| 9 | 102 | 73 | | | | | | | | | | | 4 | 0 | | | | | | | | | | | | | | |
| 10 | 101 | 78 | | | | | | | | | | | 2 | 0 | | | | | | | | | | | | | | |
| 11 | 102 | 78 | | | | | | | | | | | 3 | 0 | | | | | | | | | | | | | | |
| 12 | 100 | 77 | | | | | | | | | | | 2 | 0 | | | | | | | | | | | | | | |
| 13 | 102 | 77 | | | | | | | | | | | 2 | 0 | | | | | | | | | | | | | | |
| 14 | 102 | 77 | | | | | | | | | | | 4 | 0 | | | | | | | | | | | | | | |
| 15 | 98 | 80 | | | | | | | | | | | 2 | 0 | | | | | | | | | | | | | | |
| 16 | 96 | 72 | | | | | | | | | | | 0 | 1 | b | | | | | | | | | | | | | |
| 17 | 99 | 73 | | | | | | | | | | | 0 | 1 | 0 | | | | | | | | | | | | | |
| 18 | 96 | 75 | | | | | | | | | | | 0 | 1 | 0 | | | | | | | | | | | | | |
| 19 | 99 | 73 | | | | | | | | | | | 0 | 1 | 0 | | | | | | | | | | | | | |
| 20 | 99 | 71 | | | | | | | | | | | 0 | 2 | 0 | | | | | | | | | | | | | |
| 21 | 98 | 71 | | | | | | | | | | | 0 | 0 | 0 | | | | | | | | | | | | | |
| 22 | 97 | 76 | | | | | | | | | | | 0 | 2 | 0 | | | | | | | | | | | | | |
| 23 | 97 | 77 | | | | | | | | | | | 0 | 2 | 2 | b | | | | | | | | | | | | |
| 24 | 99 | 75 | | | | | | | | | | | 0 | 0 | 3 | 0 | | | | | | | | | | | | |
| 25 | 96 | 76 | | | | | | | | | | | 0 | — | 7 | 0 | | | | | | | | | | | | |
| 26 | 97 | 76 | | | | | | | | | | | 0 | | 3 | 0 | | | | | | | | | | | | |
| 27 | 97 | 78 | | | | | | | | | | | 0 | | 4 | 0 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | — | | 3 | 0 | | | | | | | | | | | | |
| 29 | 99 | 77 | | | | | | | | | | | | | 2 | 1 | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 | 101 | 75 | | | | | | | | | | | | | — | 2 | | | | | | | | | | | | |
| | 31 | 102 | 80 | | | | | | | | | | | | | | 0 | | | | | | | | | | | | |
| Aug. | 1 | 98 | 75 | | | | | | | | | | | | | | 1 | b | | | | | | | | | | | |
| | 2 | 100 | 71 | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | | |
| | 3 | 103 | 72 | | | | | | | | | | | | | | 0 | 0 | | | | | | | | | | | |
| | 4 | 105 | 74 | | | | | | | | | | | | | | — | 0 | | | | | | | | | | | |
| | 5 | 102 | 75 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | |
| | 6 | 104 | 75 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | |
| | 7 | 99 | 71 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | |
| | 8 | 86 | 72 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | |
| | 9 | 93 | 73 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | |
| | 10 | 97 | 74 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | |
| | 11 | 97 | 73 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | |
| | 12 | 98 | 74 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | |
| | 13 | 84 | 72 | | | | | | | | | | | | | | | 0 | | | | | | | | | | | |
| | 14 | 97 | 75 | | | | | | | | | | | | | | | 1 | b | | | | | | | | | | |
| | 15 | 100 | 75 | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | |
| | 16 | 105 | 77 | | | | | | | | | | | | | | | 2 | 0 | | | | | | | | | | |
| | 17 | 110 | 72 | | | | | | | | | | | | | | | 0 | 0 | | | | | | | | | | |
| | 18 | 114 | 75 | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | | |
| | 19 | 105 | 76 | | | | | | | | | | | | | | | — | 0 | | | | | | | | | | |
| | 20 | 96 | 80 | | | | | | | | | | | | | | | | 0 | | | | | | | | | | |
| | 21 | 99 | 70 | | | | | | | | | | | | | | | | 0 | | | | | | | | | | |
| | 22 | 100 | 67 | | | | | | | | | | | | | | | | 0 | | | | | | | | | | |
| | 23 | 100 | 65 | | | | | | | | | | | | | | | | 1 | b | | | | | | | | | |
| | 24 | 84 | 70 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | |
| | 25 | 95 | 73 | | | | | | | | | | | | | | | | 2 | 0 | | | | | | | | | |
| | 26 | 99 | 71 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | |
| | 27 | 100 | 69 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | |
| | 28 | 100 | 72 | | | | | | | | | | | | | | | | 1 | 0 | | | | | | | | | |
| | 29 | 99 | 73 | | | | | | | | | | | | | | | | 2 | 1 | | | | | | | | | |
| | 30 | 99 | 73 | | | | | | | | | | | | | | | | 1 | 2 | | | | | | | | | |
| | 31 | 101 | 74 | | | | | | | | | | | | | | | | 1 | 2 | | | | | | | | | |
| Sept. | 1 | 99 | 75 | | | | | | | | | | | | | | | | 1 | 4 | b | | | | | | | | |
| | 2 | 100 | 70 | | | | | | | | | | | | | | | | 2 | 3 | 0 | | | | | | | | |
| | 3 | 98 | 74 | | | | | | | | | | | | | | | | 1 | 1 | 0 | | | | | | | | |
| | 4 | 98 | 72 | | | | | | | | | | | | | | | | 1 | 2 | 0 | | | | | | | | |
| | 5 | 101 | 72 | | | | | | | | | | | | | | | | 0 | 2 | 0 | | | | | | | | |
| | 6 | 96 | 74 | | | | | | | | | | | | | | | | 0 | 3 | 0 | | | | | | | | |
| | 7 | 99 | 69 | | | | | | | | | | | | | | | | 0 | 3 | 1 | | | | | | | | |
| | 8 | 99 | 69 | | | | | | | | | | | | | | | | 0 | 0 | 1 | | | | | | | | |
| | 9 | 100 | 71 | | | | | | | | | | | | | | | | 0 | 2 | 1 | b | | | | | | | |
| | 10 | 103 | 68 | | | | | | | | | | | | | | | | 0 | 2 | 1 | 0 | | | | | | | |
| | 11 | 102 | 73 | | | | | | | | | | | | | | | | 0 | 0 | 2 | 0 | | | | | | | |
| | 12 | 100 | 74 | | | | | | | | | | | | | | | | 0 | — | 3 | 0 | | | | | | | |
| | 13 | 97 | 76 | | | | | | | | | | | | | | | | 0 | | 2 | 0 | | | | | | | |
| | 14 | 84 | 67 | | | | | | | | | | | | | | | | 0 | | 1 | 0 | | | | | | | |
| | 15 | 90 | 61 | | | | | | | | | | | | | | | | 0 | | 1 | 0 | | | | | | | |
| | 16 | 91 | 67 | | | | | | | | | | | | | | | | 0 | | 2 | 0 | | | | | | | |
| | 17 | 94 | 54 | | | | | | | | | | | | | | | | — | | 2 | 2 | b | | | | | | |

[1] No observations on these dates.

*Toxoptera graminum.* *Generation series showing daily reproduction, temperatures, etc. Observations made at Dallas, Tex., 1909, by T. D. Urbahns. Series begun with viviparous and ended with viviparous. No sexes*—Continued.

| Date. | Temperature. Maximum. | Temperature. Minimum. | First generation. | Second generation. | Third generation. | Fourth generation. | Fifth generation. | Sixth generation. | Seventh generation. | Eighth generation. | Ninth generation. | Tenth generation. | Eleventh generation. | Twelfth generation. | Thirteenth generation. | Fourteenth generation. | Fifteenth generation. | Sixteenth generation. | Seventeenth generation. | Eighteenth generation. | Nineteenth generation. | Twentieth generation. | Twenty-first generation. | Twenty-second generation. | Twenty-third generation. | Twenty-fourth generation. | Twenty-fifth generation. | Twenty-sixth generation. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1909. | °F. | °F. | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sept. 18 | 95 | 52 | | | | | | | | | | | | | | | | | | 1 | 3 | 0 | | | | | | |
| 19 | 97 | 61 | | | | | | | | | | | | | | | | | | 0 | 2 | 0 | | | | | | |
| 20 | 97 | 65 | | | | | | | | | | | | | | | | | | 1 | 2 | 0 | | | | | | |
| 21 | 96 | 66 | | | | | | | | | | | | | | | | | | 1 | 4 | 0 | | | | | | |
| 22 | 96 | 77 | | | | | | | | | | | | | | | | | | 0 | 4 | 0 | | | | | | |
| 23 | 84 | 58 | | | | | | | | | | | | | | | | | | 0 | 2 | 0 | | | | | | |
| 24 | 85 | 49 | | | | | | | | | | | | | | | | | | 0 | 2 | 1 | *b* | | | | | |
| 25 | 85 | 47 | | | | | | | | | | | | | | | | | | 0 | 5 | 2 | 0 | | | | | |
| 26 | 85 | 53 | | | | | | | | | | | | | | | | | | 0 | 2 | 3 | 0 | | | | | |
| 27 | 79 | 47 | | | | | | | | | | | | | | | | | | — | 2 | 3 | 0 | | | | | |
| 28 | 82 | 41 | | | | | | | | | | | | | | | | | | | 2 | 3 | 0 | | | | | |
| 29 | 89 | 41 | | | | | | | | | | | | | | | | | | | 1 | 2 | 0 | | | | | |
| 30 | 92 | 45 | | | | | | | | | | | | | | | | | | | 3 | 3 | 0 | | | | | |
| Oct. 1 | 92 | 49 | | | | | | | | | | | | | | | | | | | 2 | 3 | 0 | | | | | |
| 2 | 92 | 49 | | | | | | | | | | | | | | | | | | | — | 3 | 0 | | | | | |
| 3 | 94 | 51 | | | | | | | | | | | | | | | | | | | | 2 | 0 | | | | | |
| 4 | 92 | 51 | | | | | | | | | | | | | | | | | | | | 2 | 0 | | | | | |
| 5 | 92 | 51 | | | | | | | | | | | | | | | | | | | | 3 | 4 | *b* | | | | |
| 6 | 94 | 54 | | | | | | | | | | | | | | | | | | | | 2 | 3 | 0 | | | | |
| 7 | 91 | 57 | | | | | | | | | | | | | | | | | | | | 2 | 4 | 0 | | | | |
| 8 | 72 | 63 | | | | | | | | | | | | | | | | | | | | 2 | 4 | 0 | | | | |
| 9 | 69 | 51 | | | | | | | | | | | | | | | | | | | | 0 | 2 | 0 | | | | |
| 10 | 79 | 39 | | | | | | | | | | | | | | | | | | | | 1 | 3 | 0 | | | | |
| 11 | 64 | 45 | | | | | | | | | | | | | | | | | | | | 1 | 2 | 0 | | | | |
| 12 | 66 | 42 | | | | | | | | | | | | | | | | | | | | 1 | 1 | 0 | | | | |
| 13 | 84 | 47 | | | | | | | | | | | | | | | | | | | | 0 | 1 | 0 | | | | |
| 14 | 96 | 64 | | | | | | | | | | | | | | | | | | | | 2 | 3 | 2 | *b* | | | |
| 15 | 89 | 53 | | | | | | | | | | | | | | | | | | | | 2 | 5 | 2 | 0 | | | |
| 16 | 86 | 63 | | | | | | | | | | | | | | | | | | | | 1 | 3 | 5 | 0 | | | |
| 17 | 87 | 69 | | | | | | | | | | | | | | | | | | | | 1 | 3 | 4 | 0 | | | |
| 18 | 80 | 65 | | | | | | | | | | | | | | | | | | | | 1 | 4 | 4 | 0 | | | |
| 19 | 63 | 61 | | | | | | | | | | | | | | | | | | | | 1 | 2 | 3 | 0 | | | |
| 20 | 77 | 47 | | | | | | | | | | | | | | | | | | | | 0 | 2 | 2 | 0 | | | |
| 21 | 87 | 58 | | | | | | | | | | | | | | | | | | | | 1 | 2 | 3 | 0 | | | |
| 22 | 87 | 58 | | | | | | | | | | | | | | | | | | | | 0 | 2 | 4 | 0 | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 81 | 52 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 2 | 2 | 0 | .... | .... | .... |
| 24 | 69 | 40 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 1 | 2 | 1 | b | .... | .... |
| 25 | 77 | 42 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | 2 | 2 | 0 | .... | .... |
| 26 | 80 | 38 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 0 | 3 | 3 | 0 | .... | .... |
| 27 | 86 | 47 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | — | 3 | 2 | 0 | .... | .... |
| 28 | 85 | 54 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 3 | 2 | 0 | .... | .... |
| 29 | 81 | 49 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 4 | 3 | 0 | .... | .... |
| 30 | 82 | 57 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 3 | 4 | 0 | .... | .... |
| 31 | 83 | 67 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 1 | 3 | 0 | .... | .... |
| Nov. 1 | 80 | 44 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 1 | 4 | 0 | .... | .... |
| 2 | 83 | 43 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 1 | 3 | 0 | .... | .... |
| 3 | 86 | 42 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | 0 | 1 | .... | .... |
| 4 | 83 | 44 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 1 | 4 | 4 | b | .... |
| 5 | 80 | 57 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | 6 | 6 | 0 | .... |
| 6 | 82 | 63 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | 6 | 7 | 0 | .... |
| 7 | 82 | 60 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | 4 | 4 | 0 | .... |
| 8 | 65 | 59 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | 3 | 3 | 0 | .... |
| 9 | 73 | 44 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | 3 | 3 | 0 | .... |
| 10 | 78 | 57 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | 3 | 4 | 0 | .... |
| 11 | 82 | 68 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | 4 | 5 | 0 | .... |
| 12 | 77 | 67 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | 3 | 5 | 3 | b |
| 13 | 77 | 66 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | 5 | 5 | 7 | 0 |
| 14 | 58 | 43 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | .... | 0 | 2 | 4 | 3 | 0 |
| 15 | 71 | 47 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | — | .... | — | — | — | — | — |

Mr. T. D. Urbahns, of this bureau, carried on a series of check experiments at Dallas, Tex., in 1909, starting in March and ending in the fall. (See table, pp. 64–69.) As will be observed, and for reasons explained farther on, he did not obtain the sexes. By these experiments the maximum number of generations was secured as described under rearing methods (p. 51). The maximum number of generations in 1908 among the five series of continuous generations was 21 and, as shown below, occurred in series I of first-born; the minimum being 6 in series FF of the series of last-born. The complete series are as follows: Series B, maximum (from first-born), 20 generations; series BB, minimum (from last-born), 9 generations; series C, maximum (from first-born), 18 generations; series CC minimum (from last-born), 8 generations; series F, maximum (from first-born), 16 generations; series FF, minimum (from last-born), 6 generations; series G, maximum (from first-born), 19 generations; series GG, minimum (from last-born), 9 generations; series I, maximum (from first-born), 21 generations; series II, minimum (from last-born), 10 generations. If all of these be added, we will find the average to be 13.6 generations. This will represent the approximate number of generations for the year. In 1909 there were two series reared, A and B, both resulting the same. Series A, maximum (from first-born), 18 generations; series AA, minimum (from last-born), 7 generations; series B, maximum (from first-born), 18 generations; series BB, minimum (from last-born), 7 generations. The average for these two lines would give 12.5 generations, a little lower average than at Richmond, Ind.

Mr. Urbahns carried out one series of first-born generation experiments at Dallas, Tex., in 1909, from which he obtained only the maximum number of generations. He began March 31 and finished November 3. In this time he reared through 25 generations but did not ascertain the sexes, neither was he successful in finding them in the fields.

It appears that the species will vary in the number of generations produced from individuals hatched the same day, and from the offspring kept under the same conditions throughout the year. This will readily be understood when the amount of individual variation in molting is considered.

## AGE AT WHICH FEMALES BEGIN REPRODUCING.

The age at which females begin reproducing varies greatly between spring and summer and between fall and summer; as between spring and fall the age is very much the same. At Richmond and La Fayette, Ind., Toxoptera begins reproducing at from 5.9 to 16 days between the middle of May and latter part of September. From the time of hatching until the middle of May the period is from 20 to 27 days;

from the latter part of September to and including November the period varies from 12 to 53 days. A case occurred in the autumn of 1907 where it required 53 days for a single individual to reach maturity. This individual continued to live up to the 10th of December, when all experiments were closed. The average period from birth to reproduction for the summer months, early spring, and early fall is 9, 22, and 19 days respectively. The average for the entire year, or for the period in which the species breeds, parthenogenetically, for Richmond and La Fayette, Ind., is 16.6 days. In arriving at these averages, all individuals of the generation experiments for 1907, 1908, and 1909 were considered.

Mr. Urbahns found that at Dallas, Tex., the period varied from 7 to 12 days from birth to reproduction, from March to the middle of May; from 6 to 14 days from the middle of May until the last week in September, and from 9 to 11 days from the last week of September to November 3. The average number of days from birth to reproduction for each of these periods is 9.6, 7.4, and 9.7 days, respectively. Mr. Urbahns reared a number through December up to the middle of January. During this period the time between birth and reproduction was very much greater, varying from 18 to 25 days, with an average of 20.5 days. The average, beginning with April and continuing until November 3, is 8.9 days. From the foregoing data it will be seen that under favorable conditions Toxoptera breeds much more rapidly in the South than in the North. All of the reproduction experiments upon which these figures are based were carried on out of doors, but the insects were protected from the hot rays of the sun in the summer.

## REPRODUCTIVE PERIOD.

The period of reproduction covers a greater average length of time in spring and fall than during summer, being greatest in the spring, even though the maximum period of reproduction for a single female is practically the same for the three periods.

In computing these averages each individual of all the lines of continuous generations was considered, even though they reproduced for a single day only and then died or disappeared from some unknown cause; hence the averages are lower than they would be had these latter individuals not been considered. From this data it will be seen that both the maximum and the average periods are the greatest in the North, where the insect is able to breed continuously in unprotected places throughout the summer.

At Richmond and La Fayette, Ind., the maximum period of reproduction for individuals born from March to the middle of June is 45 days, the minimum 1 day, and the average 18 days; the maximum for individuals born from the middle of June to the middle of August

is 43 days, the minimum 1 day, the average being 12.6 days; the maximum for those born after the middle of August is 45 days and the minumum 5 days, the average being 24 days, while the average for the entire season is 16 days.

In Texas the difference between summer, spring, and fall is still more marked, December and January being about the same as the summer months. Mr. Urbahns found that during December and January the maximum reproduction period was 19 days and the minimum 2 days, the average being 8 days; during April and May the maximum was 30 days and the minimum 4 days, the average being 16.8 days; during June, July, and August the maximum was 16 days and the minimum 4 days, the average being 8.4 days; during September, October, and November the maximum was 28 days and the minimum 3 days, the average being 17 days. The average for the entire season was 13.9 days.

### LONGEVITY.

At Richmond and La Fayette, Ind., Toxoptera lives for a much longer period in the spring and fall than in the summer. In fact, in the summer it often survives a shorter time than is required for it to reach maturity in the spring and fall.

Those born from the latter part of March to the last week in May live from 15 to 78 days, the average being 43 days; those born from the first week in June to the middle of August live from 9 to 57 days, the average being 24 days; those born from the middle of August on through September live from 12 to 75 days, the average thus being 40 days. The average length of life for the whole viviparous breeding season is 35 days. These averages are not made up from the maximum and minimum alone but every individual in the line of first-born of the continuous generation experiments is considered.

Mr. Urbahns found that in Texas the spring grain-aphis lived much longer in spring and fall than in summer. In fact, in the summer it was difficult to keep it alive at all, it being necessary to keep the cages in the shade.[1] He also carried on some reproduction experiments in December and January, and in these two months found that it lived from 25 to 39 days, averaging 34 days. In April and May it lived from 13 to 47 days, averaging 35 days; in June, July, and August it lived from 10 to 30 days, averaging 17 days; in September, October, and part of November it lived from 11 to 56 days, averaging 28 days; the average for the season (from March to November) was thus 26 days.

In making up these averages only whole numbers are used, fractional parts of a day not being considered. Also, all individuals upon which we had complete observations were considered.

[1] Ante, p. 47.

## FECUNDITY OF VIVIPAROUS FEMALE.

The average person, unfamiliar with the habits of the Aphididæ, would scarcely think it possible for such small creatures to become sufficiently numerous to devastate vast areas of grainfields, destroying millions of dollars' worth of property within the space of a few weeks. When one becomes familiar with their powers of reproduction, however, the problem seems very simple.

Prof. Huxley [1] states that the tenth generation alone of a single rose aphis, were all of its members to survive the perils to which they are exposed, would contain more substance than 500,000,000 stout men. Buckton,[2] commenting on Prof. Huxley's figures, states that he much underestimates the real quantity of animal matter capable of elaboration from a single aphis in a year, and goes on to say:

Basing the calculation, for simplicity, upon the supposition that every aphis lives twenty days, and that at the expiration of that period each aphis shall have produced twenty young and no more, then at the expiration of three hundred days *only*, the living individuals would be represented by the following figures:

| Aphides. | Days. | Aphides. | |
|---|---|---|---|
| 1 produces in | 20 | 20 | = a |
| *a* produces in | $40=20^2$ | 400 | = *b* |
| *b* produces in | $100=20^5$ | 3,200,000 | = *c* |
| *c* produces in | $200=20^{10}$ | 10,240,000,000,000 | = *d* |
| *d* produces in | $300=20^{15}$ | =32,768,000,000,000,000,000 | = e |

Again, if 1,000 aphides weigh 1 grain, and

1 man weighs 2,000,000 grains

1 man weighs 2,000,000,000 aphides.

$\therefore \frac{E}{2{,}000{,}000{,}000}=1{,}638{,}400{,}000$ men; equal, perhaps, to the population of China sevenfold.

To quote further:

But a mathematical friend remarks that this calculation even does not express the real rate of increase, since it supposes the progeny of the first aphis to be produced *at once*, and not to commence producing until the expiration of the first twenty days. To this same friend I am indebted for the annexed calculation.

If we suppose the progeny of the first aphis to equal 20 in twenty days, and this progeny to begin producing when five days old 20 young, each of which again on attaining the age of five days begins the propagation of 20 young, and completes also that number in 20 days:

Then at the end of 20 days from the commencement of first aphis production there would be direct issue .......... = 20*a*

At the end of fifth day, progeny *a* begin to produce, which at the end of first 20 days will altogether equal 15+14+13+12, &c.+2+1 .......... =120*b*

At the end of tenth day, progeny *b* begin to produce, which at the end of the first 20 days will altogether equal 10+9+8, &c. +2+1 .......... = 55*c*

At the end of the fifteenth day, progeny *c* begin to produce, which at the end of the first 20 days will altogether equal 5+4+3+2+1 .......... = 15*d*

Total at the end of 20 days equals *a*+*b*+*c*+*d* .......... =210

The amount, therefore, at the end of 300 days (or 20×15) would not be less than the fifteenth power of 210, which is almost impossible to express in figures. There would be room in the world for nothing else but aphides.

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[1] Trans. Linn. Soc., vol. 22, p. 215 (part 3, 1858). [2] Monograph of British Aphides, vol. 1, p. 80.

Toxoptera, in all probability, would not fall far behind these figures and the number might even be greater. Be that as it may, the illustration will suffice to show us that Toxoptera, with such remarkable powers of reproduction, could easily overrun the whole country if not checked in some manner.

At Richmond and La Fayette, Ind., the maximum number of young produced in 24 hours was 8 in June, July, and August. The maximum number of young produced by any individual was 93, in the month of July. In Texas Mr. Urbahns found the maximum in 24 hours to be 10 young in May, and the total number of young for one individual reached as high as 84 during the same month.

At Richmond and La Fayette, Ind., considering the progeny from only the individuals of the line of first-born generations, the average number of young for the summer falls below either spring or fall, the spring being in the lead. When both the individuals from the line of first and last born generations are considered, those of the fall average less than those of the spring or summer. In 1908 the evidence was in favor of the line of first-born generations as being more prolific than the individuals of the line of last born. In 1909 the line of last-born generations held its own, especially in the spring and summer, falling behind slightly in the fall. In fact, in each line of generation experiments, the last born fall behind in average number of young in the autumn. Also, if an average be taken of the first and last born separately, the latter will fall behind. Considering each individual of both lines in all generations, both first and last together, the results are as follows: The maximum number of young produced by those born from March to the middle of June is 69, the average number for each individual for this period being 30.3; the maximum for those born from the middle of June until the middle of August is 93 young, the average number for each individual being 25.3; the maximum for those born after the middle of August is 66 young, the average for each individual being 24.

The average number of young, including every individual under observation, whether connected with the generation experiments or otherwise, for the entire viviparous breeding season, of the years 1907, 1908, and 1909, beginning the last week in March and continuing until November, both inclusive, is 28.2; there being 216 individuals used to obtain this average.

In the generation experiments were a number of individuals that produced from 1 to 10 young and then disappeared, apparently not dying from natural causes. All of these were included, however, in arriving at the final average, as any average obtained by excluding one or more individuals from any cause whatever would be more or less arbitrary, since in nature the mortality, in all probability, would be much greater. All of the rearings were carried on out of doors,

and as the individuals were isolated and protected as much as possible from natural enemies it is probably safe to say that this average is as high as would obtain in the open fields, where they are convenient prey for their enemies.

Mr. Urbahns found that in Texas the average number of young produced in the spring and fall was much greater than in the summer. The averages for December and January agree very well with those of the summer period.

The maximum number of young produced by a single individual, under observation by Mr. Urbahns, that began reproducing in December and January was 29, the average for this period being 17. 1; the maximum for those that began reproducing in April and May was 84, the average being 58.5 young; the maximum for those that began reproducing in June, July, and August was 39, the average being 17.2 young; the maximum for those individuals that began reproducing after August was 73; the average for the period from March to November is 39.7; the average for the entire number of individuals upon which Mr. Urbahns made observations during 1909, including the rearings during December and January, is 34 young. As will be observed, this is considerably above the average for Indiana.

From the foregoing data it will be seen that the spring, in both the North and the South, is the most favorable period for reproduction; in the North the summer period ranks next, the fall coming last, while in the South the summer is so hot that the aphidids can scarcely live at all, the fall ranking next to spring for productiveness.

## FECUNDITY OF WINGLESS VERSUS WINGED FEMALES.

In 1890 the senior author gathered from his observations that the wingless forms were more prolific than the winged. In 1907 the junior author came to the same conclusion. In 1909 Mr. Urbahns, in Texas, observed that the winged forms did not appear to be so prolific as the wingless forms. During the summer of 1909, at La Fayette, Ind., the junior author carried on some experiments with a view of learning, if possible, something definite in regard to this matter. For this purpose 8 nymphs with wing pads and 8 larvæ in the fourth stage were selected and each placed in a separate cage, each cage being placed under the same conditions. This experiment began on the 30th of August and all individuals became adult about the same time. The maximum number of young produced by a single winged individual was 44 and the minimum was 10; the maximum number of young produced by a single wingless individual was 61 and the minimum was 4. The total number of young produced by the 8 winged individuals was 224, or an average of 28 young for each individual; the total for the 8 wingless individuals was 274, or

an average of 34.25 young to each individual. While too small a number of individuals was taken to make the result conclusive, it plainly indicates that fecundity is greatest among the wingless individuals.

### AVERAGE NUMBER OF YOUNG PRODUCED DAILY.

By "the average daily number of young produced" is meant the daily average for the reproductive period only of each individual. At Richmond and La Fayette, Ind., the average number of young produced daily for those born from March to the middle of June is 1.9; the daily average for those born from the middle of June to the middle of August is 1.7; the daily average for those born after the middle of August is 1.2. These figures, of course, include only those individuals in the generation experiments. The average number of young produced daily for the entire year is 1.6. The final average remains the same when all individuals are considered, irrespective of generation experiments.

From the above it will be seen that the daily average is greatest in the spring, the summer coming next, and the fall last. This corresponds also to the average total number of young for each individual for these periods.

Mr. Urbahns found that the average number of young produced daily at Dallas, Tex., for those individuals that began reproducing during December and January was 1.5; the daily average for those that began reproducing during April and May was 3.4; the average for those that began reproducing during June, July, and August was 2.1; the average for those born after August was 2.5. These averages will be seen to agree proportionately with the average number of young produced by a single individual during these periods, with the exception of the daily average for December and January, which is considerably lower. The average daily number of young for the entire breeding season for which Mr. Urbahns has any data is 2.

From the above data it will be seen that the average daily number of young for Texas is far above the average for Indiana. This can probably be accounted for from the fact that the reproductive period is much longer in the North and the young are distributed over a longer period. Also the average number of young for each individual is greater in the South.

### SEXUAL FORMS.

The first young of the sexes in Indiana are apparently born the last week in September, the first adults oftentimes appearing as early as the first week of October. The adults can be found from this time on until December, or until they are killed off by extreme cold.

The males can easily be distinguished by their small size. The oviparous females (fig. 9) can be readily distinguished without a hand

lens by the yellowish areas over the abdomen, due to the fact that the eggs show through the body walls; also, if the males have not been with them, by the manner in which they rest upon the plant, the body being held at an angle of about 45° to the leaf upon which they rest. In assuming this position they hold to the plant only with the two first pairs of legs. Only unmated females rest upon the plant in this manner. The sexes may mate once or many times, although one mating is apparently sufficient to produce fertile eggs.

One agamic female may produce all agamic individuals, a combination of agamic males and oviparous females, or only true females and males. When only the latter, it seems that the females far outnumber the males.

Mr. C. N. Ainslie, in 1908, in Washington, D. C., records a very singular phenomenon. On April 4 of that year he observed males, oviparous females, and eggs of Toxoptera in his cages in the office. A number of eggs were obtained, but none of them would hatch. The source of this material, however, is somewhat obscure. Mr. Kelly had sent in material from Leavenworth, Kans., previous to these finds and this was kept breeding in the office, together with material collected locally. The junior author also found an adult male in his rearing cages in the insectary at Washington during April, 1911. This apparently developed from material that had been kept breeding all winter.

## DESCRIPTIONS.

Since in the earlier stages the young can not be distinguished from those of the summer forms, it is unnecessary to go into detail with reference to them. The males may probably be identified in the third instar by their small size; they are much smaller and the abdomen more pointed, posteriorly, than the summer forms of this stage that later will become winged. Those young that will develop into oviparous females can not be determined with any degree of accuracy until the fourth instar. They are usually a little paler in color, and, instead of embryos, light yellowish ova can be seen, with a hand lens, developing within the body (see fig. 9). The description of the male and female first appeared in the Canadian Entomologist, in an article on "Sexual Forms of *Toxoptera graminum*, Rond," by Prof. F. L. Washburn.[1] His description is as follows:

*Oviparous female.*—Length, 2-2.25 mm.; color, yellowish green, median line of abdomen darker green; head and prothorax somewhat paler than the rest of the body. Eyes black; antennæ black, except the two basal joints, and the basal half of the third, which are the same color as the head. Legs yellowish, tibia brownish toward the apex, tarsi black; cornicles greenish, their apex black; cauda greenish. Antennæ slender, hardly one-half the length of the body, no circular sensoria. Cornicles slightly tapering, not reaching to the end of the body. Cauda slender, somewhat

[1] Can. Ent., vol. 40, No. 2, February, 1908.

constricted above the middle, about two-thirds the length of the cornicles. Tibia of hind leg (fig. 10) swollen and thickly covered with sensoria-like swellings. Lateral tubercles small and single.

*Winged male.*—Expanse of wings about 4.5 mm.; length of body about 1.3 mm. General coloration of the abdomen yellowish green; head brownish-yellow; eyes black; antennæ black, except the two basal joints and the proximal half of the third, which are yellowish green. Legs yellow, the femora more or less dusky, the posterior pair darkest; apex of the tibia and tarsi black; cornicles yellowish, with black apex; cauda yellowish. Wings, costa and subcosta yellow; stigma paler, the inner edge of the stigma and the veins black. Antennæ long and slender, reaching to or a little beyond the end of the body; third joint with about twenty circular sensoria; fourth with about eighteen; fifth with about nine. Cauda slender, somewhat constricted about the middle, as long as the cornicles. Lateral tubercles small and single.

To this description we add the following:

*Oviparous female.*—Measurements of antennal joints (average from eight individuals): I, 0.067 mm.; II, 0.050 mm.; III, 0.229 mm.; IV, 0.166 mm.; V, 0.172 mm.; VI, base 0.095 mm.; VI, filament, 0.369 mm.; total length, 1.148 mm.

Male (average from six individuals) (fig. 6): I,0.064 mm.; II, 0.051 mm.; III, 0.361 mm.; IV, 0.243 mm.; V, 0.242 mm.; VI, base, 0.107 mm.; VI, filament, 0.407 mm.; total length, 1.475 mm.

We find also that the coloration of the oviparous female varies considerably from almost a clay-yellow with a faint tinge of green to a deep green. Individuals are somewhat pruinose also. As they become older the legs and bases of the antennæ get darker; each margin of the base of the cauda becomes quite dark.

The abdomen of the male varies somewhat in color from deep apple-green to pale green; the thoracic plates, dorsally and ventrally, are of an olive color.

### MOLTING.

As stated on page 62 Mr. Vickery, of this bureau, conducted some experiments at Richmond, Ind., in 1908, to ascertain the number of molts for the sexes. He selected 6 individuals just as they were born and isolated each in cages as heretofore described. Three proved to be males and 3 oviparous females, all of which molted 4 times. Also, at La Fayette, Ind., in 1909, the junior author found that the oviparous forms molted 4 times.

## OVIPAROUS DEVELOPMENT.

### AGE AT WHICH FEMALES BEGIN OVIPOSITION.

The age at which females begin depositing eggs varies greatly according to weather conditions. From 11 to 41 days are required for them to become adult. If they happen to be born the last week in September or the first week in October the chances are that they will become adult within about 11 days. If they have the misfortune to be born the last week in October or during November it may take them over a month to reach maturity; perhaps they would

not reach maturity at all in case of an early winter. After reaching maturity they will, when accompanied by the male, begin ovipositing in from 3 to 9 days; if the weather is warm, in from 3 to 4 days. The period, then, from birth to oviposition varies from about 14 to 44 or 45 days. Females will, in rare instances only, oviposit without first having been with the male. They will live unfertilized from 31 to 71 days without ovipositing, the abdomen becoming very much distended, and, upon dissection, 6 or more fully developed eggs may be found. In one case a female deposited 2 eggs without having been with a male, but no development occurred within the egg and it shriveled and dried up within a few days. When nearly through ovipositing the female becomes shrunken and misshapen, as shown in figure 15. (Compare with fig. 9.)

### PLACE OF OVIPOSITION.

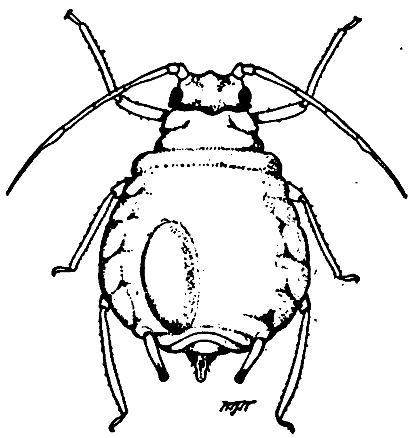

FIG. 15.—The spring grain-aphis: Shrunken and nearly spent oviparous female. Enlarged. (Original.)

Throughout the North it appears that bluegrass (*Poa pratensis*) is the most common host plant of Toxoptera, though it occasionally, on account of favorable weather conditions or the scarcity of natural enemies, becomes excessively abundant there and escapes to the grains in destructive numbers. Consequently it appears that the sexes normally occur on bluegrass. It is also true that they will be better protected from the extremes of temperature among tall, rank growing bluegrass than they would be on the grains in open, bleak fields.

In only a very few instances have we been able to find the sexes upon the growing grains in the fields. It is an easy matter, however, to locate them upon bluegrass in waste places. They apparently prefer dead or dying leaves and crawl out near the tip of the leaf, where it has begun to fold, and here deposit their eggs. (See fig. 11.) Several old females have been found at the same time within the curl of a leaf, and as many as 14 eggs have been found upon a single leaf.

### PERIOD OF OVIPOSITION.

Here again, as in the case of viviparous development, varying temperatures are probably the main factor in determining the length of the productive period. Eggs continue to develop within the bodies of the females, apparently, as the embryos do within the

bodies of the viviparous individuals, so long as warm weather continues or until the females become old and die a natural death. The viviparous forms appear to be as susceptible to extreme cold as are the oviparous individuals.

From the 14 experiments that were conducted to determine the period of oviposition it was found that it varied from 3 to about 25 days. If, after becoming adult, the female be kept for a week or more and then placed with the male it appears that the reproductive period is shortened.

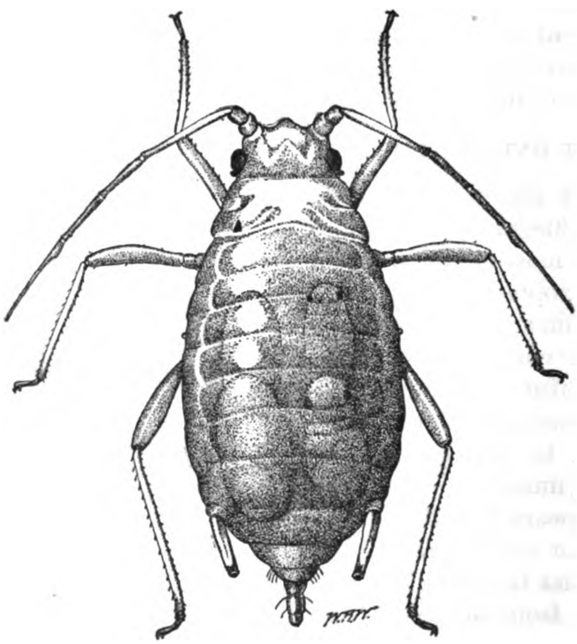

FIG. 16.—The spring grain-aphis: Aberrant female with eggs and embryos in abdomen, showing through the body wall. Enlarged. (Original.)

### LENGTH OF LIFE OF THE SEXES.

The males reach maturity, it seems, as quickly as the oviparous females, but their lives are much shorter. The males live from 8 to 10 days after becoming adult.

The length of life of the oviparous females depends principally upon two factors, namely, weather conditions and the presence of the male. Under favorable weather conditions, and in the presence of the male, they will live from 31 to 68 days. If the male is not present they will sometimes live as long as 88 days. Under these circumstances they rarely deposit eggs, only one instance, as previously cited, having come under our observation where they did oviposit and then the eggs were not fertile. Their abdomens become greatly distended with eggs, and upon being dissected, as many as six or more full-sized eggs may be found.

## FECUNDITY OF OVIPAROUS FORMS.

The oviparous forms are far less prolific than the viviparous. They produce, under favorable circumstances, from 1 to 10 eggs, or an average of 5.4 eggs per individual. This average was made up from observations on 27 individuals.

## ABERRANT INDIVIDUALS.

During our studies of Toxoptera we have found some rather interesting abnormalities. In December, 1907,[1] while dissecting some individuals in the laboratory, two were found that contained both living embryos and true eggs. In April, 1908, Mr. C. N. Ainslie found the same phenomenon occurring in individuals here in Washington. These latter resembled the wingless viviparous forms externally (see fig. 16). Mr. S. J. Hunter, in "The Green Bug and Its Enemies," finds, besides this form, what he terms "winged intermediate females, resembling the winged agamic females in antennal characteristics." Other writers mention the same phenomenon as occurring among other species of plant-lice, and no doubt these abnormalities occur much oftener than any of us are aware. At present, however, there appears to be no satisfactory explanation of such occurrences.

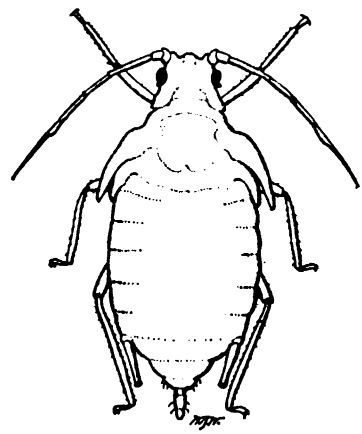

FIG. 17.—The spring grain-aphis: Aberrant female pupa which produced young. Enlarged. (Original.)

One single instance came under our observation where a puparium produced 6 young and then died. The cauda of this individual resembled that of an adult insect and the wing-pads were aborted, the abdomen being much broader than that of the normal pupa. (See fig. 17.)

## INFLUENCE OF WINDS ON DIFFUSION.

By referring to the maps (fig. 5) showing the area covered by the different outbreaks of Toxoptera in the United States, west of the Mississippi River, it will be observed that they have all had their origin in central Texas, with a single exception, extending broadly to the north and northeast. This was especially true of two most destructive invasions of 1890 and 1907, and was also implied by that of 1901, the case of 1903 having been too incipient. This strongly indicates

[1] Proc. Ent. Soc. Wash., vol. 10, pp. 11-13, January, 1908.

the presence, during each extended invasion, of some important influence that shapes, to a marked degree, the course of these invasions across the country northward and northeastward from the point of their origin in the South. Probably this is due primarily to the direction of the winds during the months between January and June.

The degree of influence exerted by the winds in the diffusion of Toxoptera is, however, dependent upon several other factors. In the first place, with wingless individuals alone present, it is clear that no amount of wind of whatever velocity would distribute the species to any considerable degree. Therefore, it is necessary to understand the vital forces that regulate the abundance of winged individuals, which, at the critical period, would probably be almost without exception viviparous females. Field observations have shown, not only among this but among other species of aphidids, that a curtailing of the food supply is a most potent influence in producing the aerial form. Not only has it been observed with Toxoptera that as the food plants lose their vigor, affording less nutrition, the winged individuals become more and more abundant in the fields, but both Mr. Phillips and Mr. Urbahns have been able, by regulating the food supply, to produce these winged individuals, artificially at will, in their rearing cages. In the case of *Macrosiphum granaria* Buckt., it has always been noticed that though the heads of wheat be literally swarming with wingless females and young, these young do not perish as the food supply becomes exhausted on account of the ripening of the grain, but develop into winged adults which fly away, leaving only the cast larval and pupal skins on the ripening wheat heads. Therefore, so long as there is an abundant supply of vigorous young grain the percentage of winged adults appearing will be comparatively few. The condition of the food supply, then, is a prime factor in the diffusion of Toxoptera, except when greatly decimated in numbers from excessive parasitism.

If the temperature be below the point of activity for the species, it is very clear that the velocity of the wind would have no effect whatever upon the diffusion of the insect. The conditions necessary, then, for the wind to exert its greatest influence will be a decreasing food supply for the insect under a temperature considerably above that actually necessary for its activity, with numbers not seriously reduced by parasites; under these conditions, many species of aphidids are known to be carried about in immense numbers by the winds.

White, in his Natural History of Selborne[1] has this reference to a migration of small aphidids.

> As we have remarked above that insects are often conveyed from one country to another in a very unaccountable manner, I shall here mention an emigration of small Aphides, which was observed in the village of Selborne no longer ago than August 1, 1785.

[1] Natural History and Antiquities of Selborne. By the Rev. Gilbert White, M. A., London, 1836, pp. 365–366.

At about three o'clock in the afternoon of that day, which was very hot, the people of this village were surprised by a shower of Aphides, or smother-flies, which fell in these parts. Those that were walking in the street at that juncture found themselves covered with these insects, which settled also on the hedges and gardens, blackening all the vegetables where they alighted. My annuals were discoloured with them, and the stalks of a bed of onions were quite coated over for six days after. These armies were then, no doubt, in a state of emigration, and shifting their quarters; and might have come, as far as we know, from the great hop plantations of Kent or Sussex, the wind being all that day in the easterly quarter. They were observed at the same time in great clouds about Farnham, and all along the vale from Farnham to Alton.

Prof. Karl Sajo calls attention to the fact that many aphidids creep to the crowns of the plant which they infest and then drop themselves at the proper moment into the boiling current of the storm.[1] In the studies made of Toxoptera many instances of this nature have been observed. It will be recalled that *Toxoptera graminum* appeared in swarms about Parma, Italy, in 1847 and again in 1852. The notes of Mr. C. N. Ainslie, made on Toxoptera in Oklahoma and Kansas, contain very many similar interesting records.

At Kingfisher, Okla., under date of March 27, 1907, Mr. Ainslie makes this record.

Toxoptera flying to-day by the million. The air was full of the migrants, and farmers who drove to town were covered on the windward side to their annoyance. The aphides seem for the most part to fly low, but the wind hurried them at such a rapid rate that they might easily have been invisible when higher in the air.

The following day his field notes contained these significant statements: "Large numbers of Toxoptera on the wing to-day, always moving north," and as those who have studied the species will understand, the most interesting statement was that "A heavy thunder shower passed by on the north last night, 30 miles away, and a few drops fell here." In the same locality, under date of April 3, he states that winged individuals of Toxoptera were taking to wing freely, for he had observed many leaving the blades in the fields and taking flight. Again, under date of April 6, "The air is full of flying Toxoptera to-day, going northeast with a light breeze. They do not fly high, from 2 to 15 feet." (The temperature at Wichita, 30 miles north, was from 42° to 57° F.) At Wellington, Kans., April 24 (with Wichita temperature 45° to 81° F.), he found Toxoptera flying by the million and farmers driving to town had to shelter their eyes from the swarm. On April 29, he records these observations:

Yesterday afternoon was warm for awhile (41° to 63° F. at Wichita), light northwest breeze. Toxoptera took wing in immense numbers for 15 or 20 minutes, drifting southwest, but soon saw their mistake and the air cleared. This is the only instance seen by me when these aphides failed to fly north. The wind did not carry them far this time. A Sunday ball game was in progress when they flew, and I was told that the myriads of aphides interfered with the game; it was like trying to play in a snowstorm.

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[1] The Wanderings of Insects. Prometheus, vol. 1, by Prof. Karl Sajo.

Under date of May 17, 1907, also at Wellington, Kans., Mr. Ainslie made an interesting record as follows:

Yesterday, the 16th, the air was full of Toxoptera rising on wing, but the breeze was light and they had no chance to travel far. If the wind had favored their flight they must have carried parasites with them as guests, by the myriad, for many of them, probably the major part, were parasitized. [The temperature at Wichita ranged from 44° to 82° F.]

On the same day the senior author, in company with Prof. E. A. Popenoe, in driving about the country in the vicinity of Manhattan, Kans., during the afternoon found that they were in the midst of swarms of winged Toxoptera; frequently a number of individuals might be noted crawling about over their hats and coats and to an annoying degree traveling over their faces. Two days later, the senior author observed both winged Toxoptera and Aphidius crawling about on the inside of the windows of a Pullman car in which he was traveling over the Santa Fe, crossing central Kansas.

At Plano, Tex., June 4, 1909, Mr. Urbahns learned of a most interesting migration reported to him as having taken place two days before. A farmer, Mr. Foreman, reported to him that "green bugs" were observed flying east, probably coming from out of a very badly infested wheat field, moving with the evening breeze. In this case there was clearly a rapid disappearing of the food supply, precipitating a development to winged adults that were probably forsaking the fields for some other locality affording them a greater abundance of food. It would appear, then, that the influence of winds is more or less dependent upon several other phenomena.

With the natural advance of spring from the South, there would be a continually decreasing supply of fresh, tender, succulent food in the South, while to the North this condition would be reversed. Therefore, with winged viviparous females developing with increasing abundance along the area of a certain latitude, such winged females as were carried south or backward over an area already rendered barren of food would consequently perish. On the other hand, those females that drifted or made their way northward would encounter a continually increasing fresh supply of food; therefore they might be said to follow along with the advance of the spring from the South far into the North, until overtaken by their natural enemies. Then, too, south winds are associated with a warm temperature and north winds with the reverse, as will be seen from Tables IV–VIII, furnished by the United States Weather Bureau. Another factor that must not be lost sight of is that after about the latitude of southern Kansas and Missouri is reached wheat ceases to be the food plant for Toxoptera in spring, and spring oats takes its place in this respect.

Still another factor of greatest importance is in the fact that, with a wind from a southern quarter, blowing strongly under a temperature sufficient to render Aphidius active, both Toxoptera and parasite would thus be carried on the wing perhaps miles to the northward and scattered over fields not previously seriously infested. The following day, or some days after, there might come a north wind with greatly reduced temperature, which, though not sufficiently cold to prevent immediate reproduction on the part of migrant Toxoptera, would yet keep the parasite inactive. That precisely these weather conditions do often occur during years of excessive abundance of Toxoptera is shown by the following tables of the weather (Tables IV–VIII), while the dates thereof show conclusively that both Toxoptera and Aphidius were present and active. This last factor will be further discussed under natural enemies. These tables were compiled for us by the Weather Bureau.

TABLE IV.—*Maximum and minimum temperatures, with direction and velocity of wind, and character of the day, San Antonio, Tex., 1907.*

| Date (1907). | Weather. | Maximum. | Minimum. | Direction of wind. | Velocity of wind. | Date (1907). | Weather. | Maximum. | Minimum. | Direction. of wind. | Velocity of wind. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | °*F.* | °*F.* | | *Miles per hour.* | | | °*F.* | °*F.* | | *Miles per hour.* |
| Feb. 1 | Clear | 81 | 63 | SE. | 11 | Mar. 3 | Clear | 80 | 49 | SE. | 13 |
| 2 | Fair | 83 | 48 | N. | 26 | 4 | ....do | 82 | 56 | SE. | 15 |
| 3 | Cloudy | 49 | 38 | N. | 22 | 5 | Fair | 84 | 64 | S. | 16 |
| 4 | Fair | 56 | 33 | NE. | 20 | 6 | ....do | 85 | 64 | SE. | 18 |
| 5 | ....do | 47 | 28 | NE. | 19 | 7 | Clear | 84 | 64 | S. | 15 |
| 6 | Cloudy | 43 | 34 | NE. | 15 | 8 | Fair | 82 | 66 | SE. | 18 |
| 7 | Fair | 60 | 39 | N. | 22 | 9 | ....do | 80 | 66 | S. | 16 |
| 8 | Clear | 68 | 33 | N. | 7 | 10 | ....do | 80 | 57 | W. | 23 |
| 9 | ....do | 73 | 38 | S. | 15 | 11 | ....do | 85 | 65 | SE. | 21 |
| 10 | ....do | 68 | 42 | N. | 22 | 12 | ....do | 87 | 65 | S. | 21 |
| 11 | ....do | 72 | 44 | N. | 10 | 13 | ....do | 80 | 70 | NE. | 17 |
| 12 | ....do | 74 | 36 | S. | 10 | 14 | ....do | 70 | 47 | N. | 36 |
| 13 | ....do | 78 | 46 | S. | 15 | 15 | Clear | 70 | 42 | NE. | 23 |
| 14 | ....do | 71 | 50 | N. | 24 | 16 | ....do | 76 | 46 | SE. | 14 |
| 15 | ....do | 70 | 40 | N. | 9 | 17 | ....do | 88 | 66 | SE. | 18 |
| 16 | ....do | 77 | 44 | SW. | 11 | 18 | ....do | 88 | 64 | SE. | 15 |
| 17 | ....do | 80 | 48 | SE. | 10 | 19 | ....do | 89 | 62 | SE. | 15 |
| 18 | Fair | 80 | 53 | SW. | 14 | 20 | ....do | 89 | 63 | SE. | 17 |
| 19 | Clear | 76 | 52 | N. | 18 | 21 | ....do | 88 | 63 | SE. | 24 |
| 20 | ....do | 79 | 44 | SW. | 10 | 22 | ....do | 87 | 64 | SE. | 20 |
| 21 | ....do | 80 | 47 | S. | 17 | 23 | ....do | 86 | 66 | S. | 15 |
| 22 | Fair | 80 | 52 | SE. | 19 | 24 | ....do | 88 | 67 | SE. | 16 |
| 23 | Cloudy | 79 | 62 | SE. | 15 | 25 | Fair | 87 | 68 | SE. | 18 |
| 24 | ....do | 67 | 56 | NE. | 22 | 26 | ....do | 86 | 68 | SE. | 20 |
| 25 | ....do | 66 | 48 | N. | 19 | 27 | ....do | 88 | 69 | SE. | 17 |
| 26 | ....do | 68 | 49 | SE. | 7 | 28 | ....do | 88 | 68 | SE. | 20 |
| 27 | Fair | 81 | 63 | S. | 15 | 29 | Cloudy | 73 | 55 | N. | 26 |
| 28 | ....do | 80 | 64 | N. | 30 | 30 | Fair | 72 | 55 | N. | 14 |
| Mar. 1 | Clear | 73 | 52 | NW. | 27 | 31 | Clear | 70 | 52 | N. | 22 |
| 2 | ....do | 77 | 43 | S. | 14 | | | | | | |

TABLE V.—*Maximum and minimum temperatures, with direction and velocity of wind, and character of the day, Fort Worth, Tex., 1907.*

| Date (1907). | Weather. | Maximum. | Minimum. | Direction of wind. | Velocity of wind. | Date (1907). | Weather | Maximum. | Minimum. | Direction of wind. | Velocity of wind. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | °*F.* | °*F.* | | *Miles per hour.* | | | °*F.* | °*F.* | | *Miles per hour.* |
| Feb. 1 | Fair | 71 | 42 | SW. | 16 | Mar. 3 | Clear | 82 | 49 | S. | 20 |
| 2 | Cloudy | 61 | 30 | NW. | 30 | 4 | ....do | 81 | 53 | SW. | 28 |
| 3 | ....do | 32 | 26 | N. | 17 | 5 | Fair | 69 | 53 | SW. | 22 |
| 4 | ....do | 30 | 22 | NW. | 16 | 6 | ....do | 82 | 51 | SW. | 23 |
| 5 | Fair | 33 | 22 | NE. | 12 | 7 | ....do | 86 | 63 | SW. | 22 |
| 6 | ....do | 42 | 24 | NE. | 9 | 8 | ....do | 70 | 53 | NE. | 17 |
| 7 | ....do | 53 | 30 | N. | 23 | 9 | ....do | 78 | 56 | SW. | 23 |
| 8 | Clear | 67 | 26 | S. | 20 | 10 | Clear | 62 | 39 | N. | 16 |
| 9 | ....do | 80 | 44 | S. | 17 | 11 | Fair | 81 | 49 | S. | 35 |
| 10 | Fair | 65 | 43 | NE. | 21 | 12 | ....do | 84 | 66 | SW. | 33 |
| 11 | Clear | 73 | 35 | S. | 16 | 13 | Clear | 78 | 44 | S. | 30 |
| 12 | ....do | 79 | 46 | SW. | 22 | 14 | ....do | 58 | 38 | N. | 20 |
| 13 | ....do | 80 | 47 | SW. | 22 | 15 | ....do | 64 | 39 | SE. | 11 |
| 14 | ....do | 61 | 42 | N. | 20 | 16 | ....do | 75 | 46 | SW. | 22 |
| 15 | ....do | 69 | 33 | SW. | 17 | 17 | Fair | 83 | 63 | SW. | 24 |
| 16 | ....do | 74 | 45 | SW. | 15 | 18 | Clear | 92 | 65 | SW. | 28 |
| 17 | Fair | 79 | 41 | S. | 20 | 19 | ....do | 95 | 64 | SW. | 25 |
| 18 | ....do | 81 | 55 | NW. | 32 | 20 | ....do | 88 | 64 | S. | 24 |
| 19 | Clear | 69 | 41 | N. | 16 | 21 | ....do | 89 | 63 | SW. | 25 |
| 20 | ....do | 74 | 40 | S. | 15 | 22 | ....do | 87 | 64 | S. | 29 |
| 21 | Fair | 74 | 44 | SW. | 25 | 23 | Fair | 87 | 65 | S. | 25 |
| 22 | ....do | 58 | 39 | E. | 16 | 24 | ....do | 86 | 64 | S. | 20 |
| 23 | ....do | 81 | 52 | S. | 25 | 25 | Clear | 85 | 67 | SW. | 31 |
| 24 | ....do | 68 | 44 | NW. | 23 | 26 | Fair | 83 | 67 | SW. | 31 |
| 25 | Cloudy | 58 | 42 | NE. | 12 | 27 | ....do | 83 | 69 | SW. | 31 |
| 26 | Fair | 71 | 40 | SE. | 18 | 28 | ....do | 84 | 70 | S. | 30 |
| 27 | Cloudy | 61 | 54 | SE. | 17 | 29 | Cloudy | 73 | 53 | NW. | 14 |
| 28 | ....do | 74 | 41 | NW. | 28 | 30 | Clear | 70 | 47 | NE. | 14 |
| Mar. 1 | Clear | 56 | 37 | NW. | 24 | 31 | ....do | 59 | 49 | NE. | 21 |
| 2 | ....do | 81 | 40 | SW. | 23 | | | | | | |

TABLE VI.—*Maximum and minimum temperatures, with direction and velocity of wind, and character of the day, Oklahoma City, Okla., 1907.*

| Date (1907). | Weather. | Maximum. | Minimum. | Direction of wind. | Velocity of wind. | Date (1907). | Weather. | Maximum. | Minimum. | Direction of wind. | Velocity of wind. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | °*F.* | °*F.* | | *Miles per hour.* | | | °*F.* | °*F.* | | *Miles per hour.* |
| Mar. 1 | Clear | 49 | 28 | N. | 30 | Apr. 1 | Fair | 66 | 38 | S. | 34 |
| 2 | ....do | 68 | 35 | S. | 35 | 2 | ....do | 75 | 48 | S. | 52 |
| 3 | ....do | 69 | 37 | E. | 23 | 3 | ....do | 88 | 58 | SW. | 43 |
| 4 | Cloudy | 84 | 45 | S. | 36 | 4 | Cloudy | 68 | 54 | N. | 36 |
| 5 | ....do | 55 | 34 | N. | 36 | 5 | ....do | 58 | 42 | N. | 38 |
| 6 | ....do | 68 | 48 | S. | 38 | 6 | ....do | 72 | 48 | SE. | 34 |
| 7 | Fair | 60 | 44 | N. | 34 | 7 | Clear | 71 | 47 | N. | 24 |
| 8 | Cloudy | 54 | 35 | E. | 25 | 8 | ....do | 63 | 44 | N. | 38 |
| 9 | ....do | 71 | 38 | NW. | 47 | 9 | Fair | 79 | 41 | W. | 31 |
| 10 | Fair | 48 | 35 | N. | 35 | 10 | Clear | 74 | 43 | S. | 26 |
| 11 | Cloudy | 70 | 39 | S. | 36 | 11 | ....do | 72 | 52 | N. | 42 |
| 12 | Fair | 68 | 43 | S. | 30 | 12 | Fair | 58 | 42 | N. | 36 |
| 13 | Cloudy | 44 | 32 | N. | 32 | 13 | ....do | 57 | 33 | NE. | 22 |
| 14 | Fair | 54 | 27 | N. | 22 | 14 | Cloudy | 61 | 44 | S. | 32 |
| 15 | ....do | 62 | 36 | S. | 25 | 15 | ....do | 85 | 49 | SE. | 48 |
| 16 | ....do | 71 | 42 | S. | 38 | 16 | ....do | 64 | 34 | NE. | 38 |
| 17 | ....do | 83 | 52 | S. | 37 | 17 | ....do | 54 | 34 | SE. | 24 |
| 18 | ....do | 89 | 60 | S. | 35 | 18 | Fair | 65 | 41 | SE. | 37 |
| 19 | ....do | 97 | 63 | S. | 32 | 19 | Cloudy | 52 | 39 | N. | 26 |
| 20 | Clear | 92 | 61 | S. | 25 | 20 | ....do | 48 | 36 | NE. | 26 |
| 21 | ....do | 89 | 64 | S. | 32 | 21 | ....do | 51 | 44 | NE. | 18 |
| 22 | ....do | 86 | 63 | S. | 34 | 22 | ....do | 46 | 40 | N. | 22 |
| 23 | Fair | 84 | 64 | S. | 31 | 23 | Clear | 69 | 36 | S. | 30 |
| 24 | Cloudy | 88 | 54 | S. | 35 | 24 | Fair | 79 | 52 | S. | 48 |
| 25 | Fair | 86 | 64 | S. | 38 | 25 | Cloudy | 64 | 40 | N. | 42 |
| 26 | Cloudy | 77 | 67 | S. | 47 | 26 | Clear | 66 | 35 | NE. | 20 |
| 27 | ....do | 83 | 68 | S. | 38 | 27 | Cloudy | 80 | 55 | S. | 36 |
| 28 | ....do | 82 | 61 | S. | 42 | 28 | Fair | 77 | 51 | SE. | 36 |
| 29 | Fair | 68 | 46 | W. | 22 | 29 | Cloudy | 64 | 34 | N. | 44 |
| 30 | ....do | 70 | 42 | N. | 31 | 30 | Fair | 50 | 32 | N. | 30 |
| 31 | Cloudy | 55 | 44 | N. | 34 | | | | | | |

TABLE VII.—*Maximum and minimum temperatures, with direction and velocity of wind, and character of the day, Wichita, Kans., from Mar. 20 to May 31, 1907.*

| Date (1907). | Weather. | Maximum. | Minimum. | Direction of wind. | Velocity of wind. | Date (1907). | Weather. | Maximum. | Minimum. | Direction of wind. | Velocity of wind. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | °F. | °F. | | *Miles per hour.* | | | °F. | °F. | | *Miles per hour.* |
| Mar. 20 | Clear | 87 | 51 | SW. | 16 | Apr. 26 | Clear | 63 | 31 | SE. | 13 |
| 21 | .....do | 91 | 63 | SW. | 24 | 27 | Fair | 77 | 48 | SE. | 19 |
| 22 | Fair | 92 | 63 | SW. | 24 | 28 | Cloudy | 63 | 41 | N. | 18 |
| 23 | Clear | 78 | 64 | SW. | 21 | 29 | .....do | 41 | 32 | N. | 27 |
| 24 | .....do | 85 | 54 | S. | 19 | 30 | Fair | 49 | 30 | N. | 16 |
| 25 | .....do | 89 | 62 | SW. | 24 | May 1 | Clear | 61 | 31 | SW. | 9 |
| 26 | Cloudy | 78 | 69 | SW. | 28 | 2 | Fair | 67 | 45 | E. | 14 |
| 27 | Fair | 69 | 47 | SW. | 17 | 3 | Cloudy | 51 | 30 | N. | 27 |
| 28 | Cloudy | 79 | 52 | W. | 30 | 4 | Fair | 50 | 28 | SE. | 15 |
| 29 | Clear | 68 | 39 | NW. | 15 | 5 | Cloudy | 50 | 43 | NE. | 13 |
| 30 | Fair | 68 | 42 | N. | 21 | 6 | .....do | 51 | 45 | NW. | 15 |
| 31 | .....do | 57 | 39 | NE. | 17 | 7 | .....do | 57 | 46 | N. | 9 |
| Apr. 1 | Clear | 65 | 37 | S. | 24 | 8 | Fair | 66 | 50 | N. | 12 |
| 2 | Fair | 71 | 49 | S. | 30 | 9 | .....do | 72 | 49 | SE. | 9 |
| 3 | Clear | 81 | 56 | NW. | 24 | 10 | .....do | 79 | 51 | NE. | 11 |
| 4 | Fair | 71 | 44 | NE. | 26 | 11 | Clear | 80 | 52 | SE. | 20 |
| 5 | .....do | 60 | 39 | NE. | 20 | 12 | .....do | 82 | 60 | S. | 35 |
| 6 | Cloudy | 57 | 42 | W. | 15 | 13 | Cloudy | 79 | 50 | S. | 24 |
| 7 | .....do | 62 | 44 | W. | 23 | 14 | .....do | 53 | 37 | N. | 27 |
| 8 | Clear | 60 | 41 | N. | 30 | 15 | Fair | 66 | 33 | NW. | 22 |
| 9 | .....do | 74 | 35 | N. | 23 | 16 | Clear | 82 | 44 | S. | 16 |
| 10 | Fair | 63 | 89 | SE. | 16 | 17 | Fair | 90 | 60 | SW. | 19 |
| 11 | Clear | 66 | 44 | NW. | 23 | 18 | Cloudy | 86 | 58 | SW. | 12 |
| 12 | .....do | 55 | 36 | NW. | 26 | 19 | Fair | 71 | 58 | NE. | 14 |
| 13 | Fair | 53 | 28 | N. | 13 | 20 | Clear | 79 | 50 | SE. | 16 |
| 14 | Cloudy | 52 | 36 | SE. | 22 | 21 | Fair | 85 | 61 | SW. | 24 |
| 15 | Fair | 74 | 46 | N. | 18 | 22 | Clear | 85 | 65 | SW. | 25 |
| 16 | Cloudy | 51 | 29 | NE. | 22 | 23 | Fair | 86 | 66 | SE. | 18 |
| 17 | Fair | 58 | 25 | SE. | 14 | 24 | Cloudy | 75 | 64 | SW. | 17 |
| 18 | .....do | 53 | 36 | N. | 25 | 25 | Fair | 82 | 55 | NW. | 14 |
| 19 | .....do | 53 | 32 | N. | 14 | 26 | .....do | 65 | 48 | N. | 26 |
| 20 | Cloudy | 52 | 37 | NE. | 14 | 27 | Clear | 66 | 37 | N. | 14 |
| 21 | .....do | 58 | 34 | N. | 9 | 28 | Cloudy | 54 | 54 | SW. | 16 |
| 22 | .....do | 56 | 43 | S. | 11 | 29 | .....do | 59 | 69 | E. | 10 |
| 23 | Clear | 73 | 36 | SW. | 17 | 30 | .....do | 61 | 61 | N. | 13 |
| 24 | .....do | 81 | 45 | SW. | 34 | 31 | .....do | 65 | 65 | N. | 21 |
| 25 | Fair | 53 | 36 | NE. | 24 | | | | | | |

TABLE VIII.—*Maximum and minimum temperatures with direction and velocity of wind, and character of the day, Dodge City, Kans., from Mar. 20 to May 31, 1907.*

| Date (1907). | Weather. | Maximum. | Minimum. | Direction of wind. | Velocity of wind. | Date (1907). | Weather. | Maximum. | Minimum. | Direction of wind. | Velocity of wind. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | °F. | °F. | | *Miles per hour.* | | | °F. | °F. | | *Miles per hour.* |
| Mar. 20 | Fair | 91 | 41 | SE. | 24 | Apr. 8 | Fair | 63 | 41 | NW. | 23 |
| 21 | .....do | 94 | 54 | SW. | 28 | 9 | Clear | 73 | 40 | NW. | 16 |
| 22 | .....do | 89 | 43 | S. | 28 | 10 | .....do | 77 | 37 | SE. | 27 |
| 23 | Clear | 76 | 53 | NW. | 23 | 11 | .....do | 64 | 38 | NW. | 24 |
| 24 | .....do | 86 | 46 | S. | 26 | 12 | Fair | 59 | 35 | NW. | 15 |
| 25 | Fair | 89 | 46 | SE. | 30 | 13 | Clear | 55 | 28 | E. | 13 |
| 26 | .....do | 85 | 54 | SE. | 36 | 14 | .....do | 68 | 35 | SE. | 26 |
| 27 | .....do | 61 | 38 | NW. | 16 | 15 | Fair | 70 | 39 | NW. | 23 |
| 28 | .....do | 74 | 44 | SE. | 35 | 16 | Cloudy | 48 | 24 | NE. | 14 |
| 29 | Clear | 62 | 30 | NW. | 24 | 17 | Clear | 60 | 24 | SE. | 16 |
| 30 | Cloudy | 59 | 31 | NW. | 18 | 18 | Fair | 51 | 32 | NW. | 18 |
| 31 | Fair | 55 | 34 | SE. | 16 | 19 | Cloudy | 45 | 30 | NE. | 10 |
| Apr. 1 | Clear | 72 | 36 | SE. | 28 | 20 | .....do | 46 | 33 | NE. | 9 |
| 2 | Fair | 85 | 51 | E. | 23 | 21 | .....do | 48 | 28 | SE. | 10 |
| 3 | Clear | 73 | 49 | NW. | 22 | 22 | Fair | 56 | 35 | SE. | 9 |
| 4 | Cloudy | 58 | 38 | N. | 15 | 23 | Clear | 78 | 30 | SE. | 18 |
| 5 | Fair | 61 | 26 | SE. | 10 | 24 | .....do | 76 | 36 | W. | 24 |
| 6 | .....do | 67 | 39 | W. | 25 | 25 | Cloudy | 44 | 31 | NW. | 17 |
| 7 | Clear | 66 | 33 | SW. | 12 | 26 | Fair | 64 | 28 | SE. | 18 |

TABLE VIII.—*Maximum and minimum temperatures with direction and velocity of wind, and character of the day, Dodge City, Kans., from Mar. 20 to May 31, 1907*—Contd.

| Date (1907). | | Weather. | Maximum. | Minimum. | Direction of wind. | Velocity of wind. | Date (1907). | | Weather. | Maximum. | Minimum. | Direction of wind. | Velocity of wind. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | °*F.* | °*F.* | | *Miles per hour.* | | | | °*F.* | °*F.* | | *Miles per hour.* |
| Apr. | 27 | Clear.......... | 81 | 37 | N. | 16 | May | 15 | Clear.......... | 67 | 30 | W. | 10 |
| | 28 | Fair........... | 59 | 32 | N. | 16 | | 16 | .....do......... | 86 | 42 | SE. | 7 |
| | 29 | Cloudy........ | 42 | 25 | N. | 18 | | 17 | Fair........... | 92 | 53 | SE. | 17 |
| | 30 | Fair........... | 45 | 20 | NW. | 7 | | 18 | Cloudy........ | 81 | 55 | NE. | 13 |
| May | 1 | .....do......... | 62 | 37 | SE. | 12 | | 19 | Clear.......... | 73 | 50 | N. | 10 |
| | 2 | Cloudy........ | 67 | 32 | NW. | 18 | | 20 | Fair........... | 81 | 50 | SE. | 24 |
| | 3 | Fair........... | 38 | 27 | NW. | 20 | | 21 | .....do......... | 86 | 60 | SE. | 35 |
| | 4 | .....do......... | 57 | 27 | SE. | 22 | | 22 | Clear.......... | 88 | 65 | SE. | 33 |
| | 5 | Cloudy........ | 48 | 41 | SE. | 8 | | 23 | Fair........... | 87 | 64 | SE. | 32 |
| | 6 | .....do......... | 50 | 42 | NE. | 7 | | 24 | .....do......... | 78 | 55 | SE. | 29 |
| | 7 | .....do......... | 60 | 40 | E. | 8 | | 25 | Clear.......... | 74 | 47 | W. | 41 |
| | 8 | Fair........... | 68 | 43 | N. | 6 | | 26 | .....do......... | 62 | 37 | NW. | 36 |
| | 9 | Clear.......... | 71 | 49 | E. | 10 | | 27 | .....do......... | 64 | 30 | SE. | 16 |
| | 10 | .....do......... | 78 | 45 | NW. | 5 | | 28 | Cloudy........ | 52 | 42 | SE. | 28 |
| | 11 | .....do......... | 84 | 48 | SE. | 24 | | 29 | .....do......... | 58 | 46 | SE. | 22 |
| | 12 | .....do......... | 90 | 60 | SE. | 31 | | 30 | .....do......... | 59 | 49 | N. | 11 |
| | 13 | Fair........... | 70 | 39 | NW. | 17 | | 31 | Fair........... | 67 | 48 | NW. | 24 |
| | 14 | Clear.......... | 55 | 34 | NW. | 16 | | | | | | | |

## INFLUENCE OF TEMPERATURE ON DIFFUSION.

Directly and indirectly, temperature is responsible for the destructive abundance of *Toxoptera graminum* in the United States. Directly, because the species will breed throughout the winter months at a temperature under which its natural enemies will remain inactive, and besides, it is probably due to this influence that the sexual forms and eggs occur, so far as known, only over the northern portion of its range. Our extended investigations have led to the suspicion that, but for the viviparous reproduction in such overwhelming numbers in the South, during winter end early spring, to drift northward with the season, there would be little if any damage caused by its occurrence in the Northern States, where in fairly severe winters it probably winters over in the egg stage only. For this reason the authors have thought investigations of the egg and its development of decided economic as well as scientific importance, and the junior author has therefore made a brief study of the embryology of the species.

The temperatures prevailing over the country where Toxoptera has worked its most serious ravages, and departures from the normal during the season of greatest activity are all given on the temperature diagrams, Nos. I to V (pp. 15, 21, 25, 26, 28). The upper numbers indicate the normal temperature, the lower the departure therefrom ("+" meaning above and "–" below). Each separate page relates to one of each of the five consecutive outbreaks. From these it will be seen that outbreaks of Toxoptera have succeeded only winters with

the temperature in the South above the normal, followed by springs during which the temperature was below the normal. The temperature during December, 1902, was below the normal in the Southwest. (See Diagram II.) In January, 1903, it was above, but below again in February, and about normal or above in March and April, the result being that only incipient outbreaks occurred in northern Texas and probably South Carolina. (See Diagram II; fig. 5, p. 20.) If the series of temperature maps (Diagrams I–V) be compared with those showing the area covered by each invasion the relation between abnormal temperatures and these invasions will be clearly apparent.

These records are those of the United States Weather Bureau and are therefore correct so far as general field temperatures are involved. When it comes to a consideration of the exact effects of temperature and humidity upon the individual Toxoptera, however, the figures will not apply with mathematical exactness, for the reason that to secure this information it is necessary to learn the exact conditions in the midst of the insects themselves at the exact time that such data are being secured. To illustrate, the instruments of the Weather Bureau kept in the shade may indicate a certain temperature, yet in a field perhaps a mile distant on a sunny day, and down among the plants in the midst of the developing insects, there may be several degrees difference in temperature. As will be noted farther on, Mr. Luginbill has found this difference to amount in some cases to several degrees. Besides, it is easy to conceive of other conditions which might have precisely the reverse effect. Furthermore, there will be a difference in temperature as between fields with a sandy and a clay soil or between a southern and a northern exposure, or with a soil dry on the surface as against a soil with a wet surface. It will be observed, therefore, that while the exact temperature at which Toxoptera will reproduce, viviparously, is of scientific interest, such information is of minor significance in the field, where it is the more generally prevailing weather conditions, such as are secured by the United States Weather Bureau, over wide areas that become of greatest importance, Mr. R. A. Vickery, on December 4, 1908, at Richmond, Ind., with 5 viviparous females under observation, found that young were produced sparingly at a temperature of 40° F. This was indoors, in a room slightly heated by an oil stove so that the temperature was under control, and frequent readings were made during the day. Under the same conditions numerous young were produced when the temperature reached 45° to 53° F.

Tabulated, the results of Mr. Vickery's rearings are as follows:

TABLE IX.—*Experiments with 5 viviparous females of Toxoptera graminum to determine minimum temperature at which reproduction will take place. Richmond, Ind., December, 1908.*

| Date. | Temperature. | | Number of young produced. |
|---|---|---|---|
| | Minimum. | Maximum. | |
| | *°F.* | *°F.* | |
| Dec. 3 | 40 | 45 | 0 |
| 4 | 40 | 41 | 1 |
| 5 | 40 | 53 | 6 |
| 6 | 40 | 45 | 0 |
| 7 | 26 | 49 | 1 |
| 8 | 35 | 50 | 7 |
| 9 | 39 | 50 | 0 |

After December 9 the outside temperature increased so that control indoors was not possible.

At Dallas, Tex., January 3 to 14, out of doors and under natural conditions, with thermometer within a few feet of the five female Toxoptera 1 to 3 days after maturity, Mr. Urbahns found that young were produced as follows:

TABLE X.—*Experiments with 5 viviparous females of Toxoptera graminum to determine minimum temperature at which reproduction will take place. Dallas, Tex., January, 1908.*

| Date. | Temperature. | | Number of young produced by each individual. | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Minimum. | Maximum. | | | | | | |
| | *°F.* | *°F.* | | | | | | *Total.* |
| Jan. 3 | 47 | 68 | 1 | 1 | 1 | 1 | 1 | 5 |
| 4 | 55 | 78 | 3 | 3 | 1 | 5 | 4 | 16 |
| 5 | 37 | 69 | 3 | 3 | 1 | 2 | 2 | 11 |
| 6 | 22 | 42 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 21 | 32 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 29 | 45 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 44 | 74 | 4 | 2 | 0 | 3 | 4 | 13 |
| 10 | 37 | 74 | 4 | 4 | ([1]) | 3 | 5 | 16 |
| 11 | 14 | 15 | 0 | 0 | ...... | 0 | 0 | 0 |
| 12 | 10 | 22 | 0 | 0 | ...... | 0 | 0 | 0 |
| 13 | 21 | 32 | 0 | 0 | ...... | 0 | 0 | 0 |
| 14 | 32 | 71 | 0 | 0 | ...... | 0 | 0 | 0 |
| Total.. | ............ | ............ | 15 | 13 | 3 | 14 | 16 | ...... |

[1] Died.

Further observations made by Mr. Urbahns on these same dates with eight additional females, the offspring of which were not counted, are of much interest and are given herewith.

January 3. Two reproducing.
January 4. Four reproducing, 1 pupating.
January 5. Five reproducing.
January 6. All torpid, seemingly frozen.
January 7. All torpid, seemingly frozen.
January 8. All torpid, none reproducing.
January 9. Seven reproducing, 1 still pupa.
January 10. Seven reproducing, 1 still pupa.
January 11. All torpid, seemingly frozen.
January 12. All torpid, seemingly frozen.
January 13. All torpid, seemingly frozen.
January 14. Adults and young fallen from the plants and lying on the ground. All except 3 inactive.

One female of the first five died on the 10th and nearly all of the others survived but a few days; only one was alive on the 20th.

During the spring of 1908 the junior author was engaged in an extensive series of rearing experiments at Richmond, Ind. Both plants and insects were kept out of doors in a small rearing house (see Pl. II, fig. 1), with a thermograph placed in their midst, so that exact temperature changes were continuously recorded. Plants were grown in flowerpots and over them in each case was placed a lantern globe with the top covered with cheesecloth. Whatever the effect of this inclosure and cover might have been it was evidently uniform and, therefore, affected all of the viviparous female Toxoptera on these plants to the same degree.

Taking five viviparous females, each a stem mother, colonized separately on single plants, in a precisely similar inclosure, and keeping a record of the number and date of young born, we have the following tabulated results:

TABLE XI.—*Effect of temperature on reproduction of Toxoptera graminum, Richmond, Ind., 1908.*

| Date. | Temperature. | | Number young produced by each individual. | | | | | Total No. | Date. | Temperature. | | Number young produced by each individual. | | | | | Total No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minimum. | Maximum. | | | | | | | | Minimum. | Maximum. | | | | | | |
| | °F. | °F. | | | | | | | | °F. | °F. | | | | | | |
| Apr. 18... | 55 | 63 | 2 | .... | 2 | 0 | 2 | 6 | May 1..... | 29 | 56 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19... | 50 | 70 | 4 | 2 | 2 | 1 | 2 | 11 | 2..... | 35 | 47 | 0 | 2 | 1 | 0 | C | 3 |
| 20... | 39 | 68 | 2 | 2 | 2 | 0 | 0 | 6 | 3..... | 37 | 55 | 1 | 2 | 2 | 1 | 0 | 6 |
| 21... | 33 | 68 | 2 | 2 | 2 | 1 | 0 | 7 | 4..... | 41 | 50 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22... | 35 | 74 | 2 | 1 | 1 | 1 | 1 | 6 | 5..... | 49 | 52 | 0 | 0 | 0 | 0 | 1 | 1 |
| 23... | 52 | 79 | 2 | 5 | 5 | 1 | 1 | 14 | 6..... | 49 | 76 | 1 | 2 | 2 | 0 | 0 | 5 |
| 24... | 60 | 71 | 3 | 3 | 4 | 0 | 1 | 11 | 7..... | 41 | 63 | 0 | 0 | 1 | 0 | 0 | 1 |
| 25... | 61 | 74 | 3 | 4 | 5 | 1 | 2 | 15 | 8..... | 41 | 49 | 1 | 0 | 0 | 0 | 0 | 1 |
| 26... | 53 | 80 | 3 | 5 | 3 | 3 | 0 | 14 | | | | | | | | | |
| 27... | 42 | 67 | 0 | 2 | 2 | 3 | 1 | 8 | Total............. | | | 29 | 32 | 36 | 15 | 12 | .... |
| 28... | 38 | 54 | 2 | 0 | 0 | 0 | 0 | 2 | Total progeny during life................ | | | 60 | 47 | 69 | 39 | 29 | .... |
| 29... | 36 | 46 | 1 | 0 | 2 | 3 | 1 | 7 | | | | | | | | | |
| 30... | 33 | 47 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |

Of the five individuals involved in Table XI the two last hatched from the egg March 24, the other three on March 27. This table indicates the influence of high temperatures on reproduction, but also shows that these affect the individual female to varying degrees. The totals for the life of individual females show that all of these were in the vigor of life, not having reached the decline at the time the observations were made.

These tabulations are taken from records of regular rearing and reproduction investigations, and were selected wherever there occurred a number of consecutive days with temperatures varying both above and below freezing during each 24 hours.

By referring to the continuous rearing by the junior author it will be observed that with favorable conditions a female Toxoptera will produce young every day during the most vigorous portion of her life, the exceptions being toward the close thereof.

It would probably be well to mention in this connection some observations of the junior author in regard to the amount of cold that can be endured by Toxoptera.

On November 13, 1908, several viviparous females that had been producing young were frozen solidly in a block of ice. They were thawed out after 8 and 24 hours, respectively, and all died. These may have been somewhat weakened by age, however, so on the 14th 2 oviparous females, 1 winged viviparous female, 1 adult viviparous, and 2 individuals that had cast the third molt were frozen in a block of ice and allowed to remain so for 24 hours. About an hour after being thawed out, at a temperature of about 45° F., 1 oviparous female and the winged female turned dark and died, the others keeping color, but showing little signs of life. About 3 hours after there were signs of life among the remaining ones; 7 hours after thawing out they were still feeble; 24 hours after thawing out the temperature was raised to 60° F and 1 molted. On the third day after being thawed out there were 2 young in the cage. Six days later all were dead except the one that was giving birth to young, and her progeny. This will give some idea of the tenacious grip Toxoptera has on life.

Attention may properly be called to the fact that unless the utmost caution is employed in the examination of plants for newly-born young there is great likelihood that some of them may be overlooked. Thus they may be born one day under a high temperature but remain undiscovered until later, when the temperature is much lower, and of course be credited to the later date. In the light of all of the observations made by those engaged in these investigations, the minimum temperature under which reproduction begins is about 40° F. Possibly reproduction may occur under some obscure favorable circum-

stances at a slightly lower temperature, but these instances are probably too infrequent to become of economic importance.

With the eggs in the North the case may be more important, because these, deposited in dead leaves of bluegrass, and sometimes probably buried under several inches of this matted grass, with the living leaves covering this over, the temperature and moisture would both be greater than at several feet above ground without such protection. Mr. Philip Luginbill of this bureau in April, 1911, proved this to be true. He placed a thermometer in just such a position as mentioned above, in a protected nook where the sun could shine directly on it in the grass and no wind could reach it and found that the temperature was 10° to 12° F. higher than when the thermometer was several feet above the ground and in the shade. The junior author has found that eggs are deposited in just such places, and that hatching takes place in spring at a temperature ranging, as recorded by the thermograph, from 32° to 62° F. It would appear that eggs deposited in a position as mentioned above would hatch sooner than those deposited in places where the temperature would not be so high and the stem mothers from the former would reproduce, the pest becoming more abundant in the spring and making its way from grass to grain earlier and in greater numbers than they would from the cooler locations.

This leads us to a very interesting and important point in temperature effects on the species. In the South, seemingly south of about latitude 35° to 36° north, it has been impossible to find eggs of this and other species of aphidids in the fields. There is in the perpetuation of the species no apparent need of this stage, however, as it is able to continue throughout the entire year reproducing viviparously. In the North this is probably not possible except during very mild winters. The situation is therefore about like this: Gradually as we proceed southward from about latitude 38° the sexual forms and eggs disappear, while to the north of about latitude 36° hibernation is confined more and more to the egg stage, until this becomes exclusively the state in which the winter is passed.

The practical, economic importance of this is that there is considerable doubt relative to the amount of injury the pest would cause north of this belt of country if there were no Toxoptera drifting in from the south. In other words, but for the countless myriads developing south of this belt and sweeping over and beyond it, there would be few if any destructive ravages. If this is the true state of affairs, the oats crop north of this belt is to a certain degree dependent upon the success or failure in controlling the pest in Texas, Oklahoma, New Mexico, and South Carolina.

Summarizing, then, it would appear from the information we have been able to obtain, and which is given throughout this publication,

together with that contained in the various tables and diagrams relating to temperature effects upon this insect: (1) That mild winters are of much more vital importance in Texas than they are in the latitude of southern Kansas and northward, and (2) that the influences of abnormally warm weather, if the temperature rises high enough, have the effect of bringing about activity among the parasites, which has a restraining effect upon the increase of Toxoptera.

In the North, where the pest winters over wholly or largely in the egg stage, warm winters are of less importance, while abnormally cool weather during spring and early summer exerts a far greater influence. This fact renders a study of the embryology and temperature effects upon eggs and stem mothers necessary to a full understanding of the entire problem, extending as it does over both North and South.

The fact just stated is somewhat peculiar and was unexpectedly revealed by the combined studies of those engaged in the investigation of the insect, and called for a study of the development of the egg, which has been carried on by the junior author with the results given in the following pages. The most important influence of temperature is, of course, upon the development of its principal natural enemy, *Aphidius testaceipes*, further discussed in connection with the studies of that insect.

## EMBRYOLOGY.

Although the development of the parthenogenetic egg in Aphididæ has received considerable attention from several authors, that of the true egg has received very little study. Hence the junior author has given a limited amount of time to the study of certain important phases in the development of the winter egg, as contrasted with the winter condition of the viviparous insect in the South.

Not wishing to duplicate the work of the other writers, who have confined their studies for the most part to the earlier stages of development, he has begun with the formation of the blastoderm, his main object being to follow the principal stages of development of the embryo through the fall until growth is checked by freezing temperatures, to note the time when growth is resumed in spring, and to observe the effect of varying temperatures on development, all of which has to do with the fluctuations of the insect in point of numbers in the North and relates to its economic importance, besides balancing our knowledge of the insect at a corresponding season in the South.

Most of these studies were carried out at the University of Illinois under the supervision of Dr. J. W. Folsom. We are deeply indebted both to him and to Dr. W. M. Wheeler of Harvard University for their kindly criticisms and helpful suggestions.

## METHODS AND MATERIAL.

The material used in this investigation was collected in the autumn of 1908 at Richmond, Ind., and in 1909 and 1910 at La Fayette, Ind. The eggs were killed and fixed mainly in two solutions that are practically the same. The first was a saturated solution of bichlorid of mercury (corrosive sublimate) in 35 per cent alcohol, 95 volumes, and glacial acetic acid, 5 volumes. The second was a saturated solution of bichlorid of mercury in 50 per cent alcohol, 94 volumes, and glacial acetic acid, 6 volumes. The fixing fluid was raised to a temperature of 75° to 80° C., poured over the living specimens, and allowed to act from 5 to 10 minutes, after which it was replaced by the same solution, cold, for an equal length of time. The specimens were then washed in 70 per cent alcohol, in which they were kept until sectioned. Gibson's fluid was found to be a very good killing and fixing agent also.

For sectioning, the following method was employed: The eggs were punctured with a fine needle, dehydrated, and kept 20 to 30 minutes in paraffin of about 54° C. melting point. They were oriented in a watch glass (that had previously been smeared with glycerin) with a hot needle, under a binocular microscope, the bottom of the watch glass being first quickly cooled with a little cold water.

The eggs were cut with a Minot-Zimmermann microtome in sections from 8 to 13 $\mu$ in thickness, attached to the slide with Mayer's albumen fixative, and stained with Delafield's hæmatoxylin or by Heidenhain's iron-alum-hæmatoxylin method.

Surface views of the embryo were obtained by dissection. For dissections it was found that the best results were obtained by using material that had been freshly fixed and washed. Grenacher's alcoholic borax-carmine was used for staining in toto.

## GENERAL DESCRIPTION OF THE EGG.

The eggs are broadly elliptical with a slight reniform tendency. They are 0.70 to 0.78 mm. in length and 0.33 to 0.45 mm. broad.

At oviposition the egg is a very pale yellow, changing in a few hours, at a temperature of 50° to 70° F., to a faint greenish color. At this stage there appears an almost circular area of darker green at one pole of the egg; we have termed this the "ovarian yolk," a brief description of which occurs in the following pages. At the end of 24 hours the walls of the egg about the ovarian yolk appear denser and of a deeper green. The germ band is now forming and invaginating. During the next 24 hours this process is completed, the egg becoming a darker green in the meantime. By the third day a rod-shaped body can be seen near the center of the egg. This object is the submerged germ band. By the end of the third day the egg becomes black.

All these changes can be readily observed with a hand lens by holding the egg up to the light. At low temperatures (below 40° F.) these changes take place slowly, 10 or more days being required for the egg to turn black, if the temperature is near the freezing point. The black coloration is apparently due to a pigment in the shell; the green color, to the developing embryo.

At deposition the egg is coated with a viscous substance which hardens in a few days, fixing the egg firmly to the object upon which it rests.

There are but two membranous coverings to the ripe egg, the chorion, or shell covering, and the vitelline membrane.

The chorion is a rather tough, leathery, homogenous membrane which under a hand lens appears smooth and shining. With a compound microscope very faint lines or cracks can be sometimes observed on the surface, although usually the surface appears perfectly smooth, with no markings whatever.

The vitelline membrane is structureless, colorless, and transparent. Under the vitelline membrane is the peripheral layer of protoplasm. This layer is very thin and very finely reticular. It is continuous over the surface of the egg, the cleavage cells lodging in it to form the blastoderm.

Internally the egg consists chiefly of a compact mass of yolk granules, supported within the meshes of almost clear protoplasm. The yolk granules are structureless and subspherical in shape and vary greatly in size, ranging from 0.0027 mm. to 0.013 mm. in diameter.

At the posterior pole of the egg is a large, dense, almost spherical, granular mass. These granules are 0.0019 mm. in diameter, are almost uniform in size, and the central area apparently takes the stain slightly as though it were a chromatinlike substance. As previously stated, we have termed this mass the ovarian yolk. It is evidently not homologous to the secondary yolk of the parthenogenetic embryos. The ovarian yolk is formed approximately at the same time as the formation of the main yolk mass of the egg, while in the case of the parthenogenetic forms of aphidids the secondary yolk enters the egg as the blastoderm is forming. It appears also, from our material, that this ovarian yolk is not exactly homologous to the "pole disk" described and observed by Hegner (1908), as we have not been able to observe that it affects the nuclei in any way, nor have we found any cells which we think correspond to his "pole cells." The function of this granular mass seems to be the nourishment of the developing ovaries, and we have therefore called it ovarian yolk. It is not entirely used up in the early stages of embryonic growth, and remains in close proximity to the developing ovaries throughout the later stages.

Tannreuther (1907, pp. 631, 632) states that in the species he studied some of the follicular nuclei of the wall of the oviduct which enter the posterior pole of the egg divide several times, the chromatin breaking up into smaller parts and becoming vesicular. These small vesicles then usually unite and form a common spherical mass, though in some cases they remain isolated.

In *Toxoptera graminum* we find no trace of true nuclei within the ovarian yolk (the homologue of Tannreuther's secondary york of the winter egg) until the blastoderm is formed, at which time cells may be found that are apparently migrants from the primary yolk.

## OBSERVATIONS.

For convenience of reference 9 consecutive stages of development are here designated, as follows:

*Stage 1* (Pl. III, fig. 1).—Blastoderm just forming, only part of the surface being covered by the cleavage cells.

*Stage 2* (Pl. III, figs. 2–4).—This shows early and later stages of invagination of the germ band. The position of the ovarian yolk in relation to the invaginating germ band is shown here.

*Stage 3* (Pl. IV, fig. 1).—The germ band is still adhering to the posterior pole of the egg.

*Stage 4* (Pl. IV, figs. 2, 3).—The germ band is entirely submerged in the yolk, is tubular in form, and uniform in thickness.

*Stage 5* (Pl. IV, fig. 4).—During the fifth stage the germ band has differentiated into the amnion and the germ band proper.

*Stage 6* (Pl. V, fig. 1).—The germ band shows differentiation into layers, and the fundaments of the segments are evident.

*Stage 7* (Pl. V, fig. 2; Pl. VI, fig. 1).—The fundaments of the appendages have appeared and the invaginations for the stomodæum and the salivary glands are evident.

*Stage 8* (Pl. V, fig. 3; Pl. VI, fig. 2).—The appendages are much longer, and the invaginations for the stomodæum and proctodæum are well advanced. The latter is not indicated in Plate V, figure 3, as the last segment curves backward too far.

*Stage 9* (Pl. VII, figs. 1, 2, 3, 4).—The illustration of this stage is intended mainly to show the manner in which the embryo reaches the surface and the position of the dorsal organ.

In *Stage 1* (Pl. III, fig. 1) the blastoderm is beginning to form. As the cleavage cells become more numerous within the yolk-mass some of them migrate to the surface and lodge within the peripheral layer of protoplasm, where, according to Tannreuther (1907), they divide again, the protoplasm of the nuclei merging with that of the peripheral layer. The formation of the blastoderm takes place more rapidly in the region of the anterior pole, the posterior being the last covered;

the entire layer is then one cell in thickness. The blastoderm, however, does not cover the surface of the ovarian yolk.

Not all of these cleavage cells reach the surface; many remain behind, increasing in number within the yolk. These latter cells are indistinguishable from those of the blastoderm. Figs. 1a and 1b represent two of these cells magnified 845 diameters, showing them to be star-shaped masses of protoplasm with a large oval coarsely granular nucleus, more often with a large clear area of nuclear substance around the mass of chromatin granules.

At the posterior pole, about the ovarian yolk, the blastoderm begins to thicken and to invaginate (Stage 2, Pl. III, figs. 2–4). This is the beginning of the germ band. At this stage (*Stage 2*) some of the yolk cells apparently pass into the ovarian yolk. Tannreuther (1907, p. 631) states that the thickening of the blastoderm is caused by the rapid division of the blastoderm cells of this particular part. We find, in addition, that some of the cells from the interior of the egg migrate to the posterior pole to assist in this process. Each of the cells of this thickened area is very elongate, and, from a surface view, now has a somewhat polygonal shape, with a large coarsely granular nucleus. The growth of the cells of the germ band carries the ovarian yolk toward the center of the egg (see Pl. III, fig. 4). The part of the blastoderm that invaginates first becomes the posterior part of the embryo, and that part that invaginates last becomes the anterior portion.

In *Stage 3* (Pl. IV, fig. 1) the germ band is ready to free itself from the blastoderm. The former is now cone-shaped, the base being closed by the ovarian yolk.

When the germ band releases itself from the blastoderm, it leaves behind what we have termed the "polar organ:" A cluster of cells embedded within a mass of protoplasm. These cells soon group themselves into a more or less spherical mass, with a less dense vacuolar area at the center (see Pl. IV, fig. 4). In later stages this central area appears denser and structureless, as though filled with a fluid, and is of a yellow color, not taking the stain, and opening directly upon the surface of the egg. For these reasons we suggest that it may be an organ of excretion. When development ceases in the fall, this body is still present.

What was formerly the blastoderm now becomes the serosa. The cells are much more widely spaced now and this wall is much thinner, except at the anterior pole, where the cells are apparently crowded more closely than before. Some of these cells often show large vacuoles on the side toward the yolk.

At *Stage 4* (Pl. IV, fig. 2) the germ band is completely submerged in the yolk, has assumed a tubular shape, and is near the center of the egg. The walls are of uniform thickness and composed of a com-

pact mass several cells thick, some of which are vacuolated, and having a coarsely granular nucleus. Figure 3 of Plate IV shows a cross section—slightly oblique, however—of the germ band.

The yolk granules of the primary yolk are now more numerous near the embryo.

In *Stage 5* (Pl. IV, fig. 4) the germ band has clearly differentiated into the amnion and the embryo proper; these gradually merge into each other. This differentiation apparently takes place by a gradual migration of cells to one side of the germ band. The cells of the amnion at this time resemble very closely those of the germ band proper. The germ band begins to fold in this stage and its anterior extremity begins to broaden and flatten. The ovarian yolk has decreased in volume and has assumed a more anterior position in relation to the embryo. The yolk cells in both the primary and ovarian yolk have lost somewhat their amœboid character, and now consist, each, of a large granular nucleus, with a much thinner area of protoplasm about it. The primary yolk granules are smaller and much less numerous than before and are collecting in masses about the yolk cells, with indications here and there of a partition, or wall, forming between them. This stage is reached by the end of the second day, under favorable weather conditions.

The "polar organ" and protoplasm at the posterior pole contain a large central vacuolar area now.

In *Stage 6* (Pl. V, fig. 1) the germ band has greatly increased in length, is folded upon itself, and almost forms a loop, the anterior and posterior extremities nearly touching, and both pointing to the posterior pole. A portion of the posterior extremity of the germ band is again folded upon itself. It is now differentiated into three layers, which we take to be, respectively, ectoderm, mesoderm, and entoderm. The ectoderm and mesoderm consist of a compact mass of columnar cells, two cells thick. The entoderm is much thinner and less compact and forms an almost continuous sheet over the inner surface of the germ band. Its cells resemble yolk cells very closely.

In this stage fundaments of the body segments appear as slight elevations of the ectodermal surface. The ovarian yolk has assumed a more anterior position in relation to the embryo than in the preceding stage. Between the ovarian yolk mass and the germ band is a group of cells that have apparently separated off from the mesoderm. From this group of cells, in later stages, the generative organs arise. The amnion now covers the ventral surface of the embryo and the other surface of the embryo is in contact with the yolk. The amnion is a very thin, delicate membrane, its cells being widely spaced and quite small. The intervening protoplasm between the cells of the serosa has become more constricted and the cells have taken more of an elongated oval shape. The primary yolk has now become defi-

nitely segmented into more or less spherical masses, separated by thin walls, each area or mass containing a number of yolk granules and from one to several cells. The polar organ is now almost spherical, with a central, pear-shaped area of dense, structureless, non-staining matter of a yellowish color, and an anterior opening. Although this evidence is insufficient it possibly indicates that the function of this organ is excretory. The embryo reaches this stage of development about the third day, under favorable conditions of temperature.

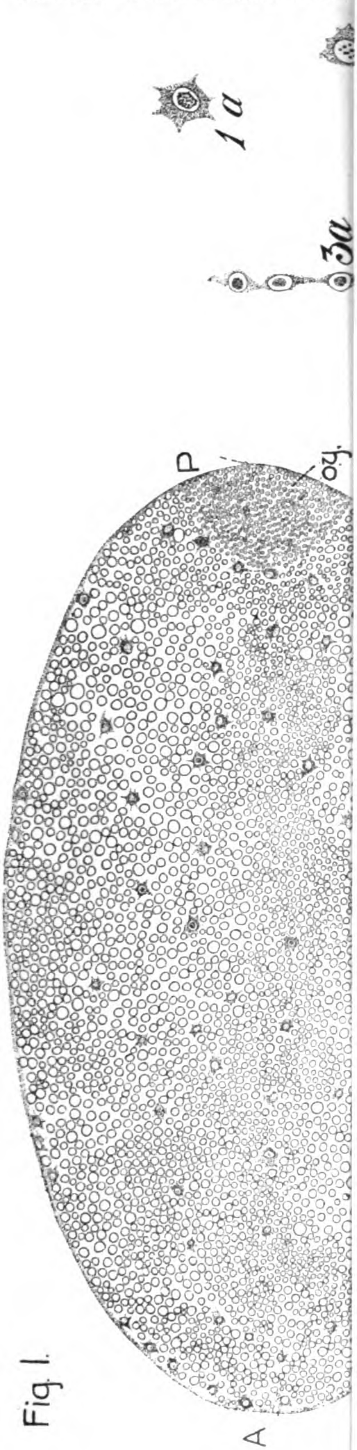
In *Stage 7* (Pl. VI, fig. 1) the embryo has changed its position so that from a side view it has the form of a reversed figure 6. The portion that in the preceding stage was folded upon itself ventrally has reversed its position and folded back dorsally. The ovarian yolk is now in the region of the first abdominal segments. It is in contact with the embryo, and the group of cells that separated it from the embryo in the preceding stage has assumed almost a spherical form, and a more posterior position, forming the genital organs later on.

The three primary regions, cephalic, thoracic, and abdominal, are now sharply marked. Each region is distinctly segmented. The cephalic region has 5 segments indicated, the thoracic 3, and the abdominal 9, the last abdominal being relatively quite large. There are now 15 conical appendages. The antennæ arise from the posterior margin of each cephalic lobe. The labrum is between and slightly anterior to the antennæ. The mandibles are nearer the median plane than the fundaments of the maxillæ and the labium. The next three pairs of appendages represent the first, second, and third pairs of legs. Plate V, figure 2, represents a surface view of stage 7, showing the embryo straightened out and the position of the appendages. All of these appendages are evaginations of the ectoderm, cross-sections showing an external layer of ectoderm cells and an inner layer of mesoderm cells.

The stomodæum (Pl. VI, fig. 1) appears now as a simple invagination of the ectoderm, the posterior wall of the labrum forming its anterior wall. The proctodæum has not yet appeared, The salivary glands (Pl. VI, fig. 1) are represented by a deep, bilobed, ectodermal invagination between the cephalic and thoracic regions. There is now a star-shaped mass of protoplasm about the nucleus of the ovarian yolk cells and the yolk granules are grouped around these cells.

The primary yolk is grouped very much as in the preceding stage with the exception that the masses are smaller and do not contain as many nuclei.

The polar organ is smaller than formerly, with a smaller number of cells. It still contains a yellowish mass and communicates with the outer surface of the egg.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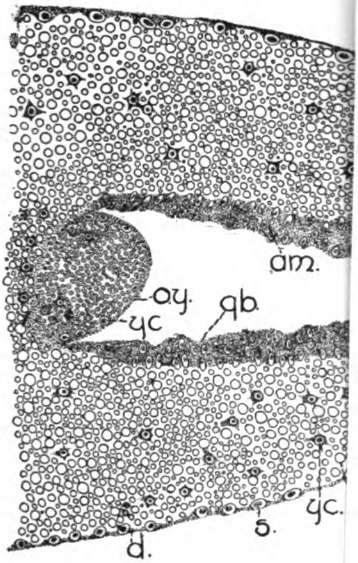
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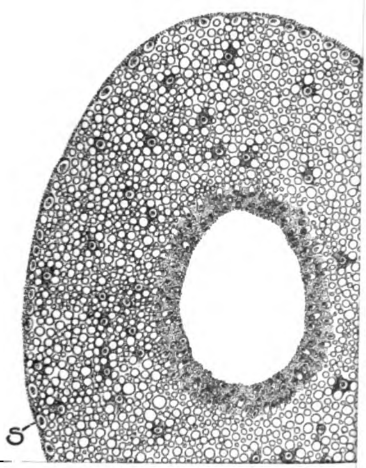
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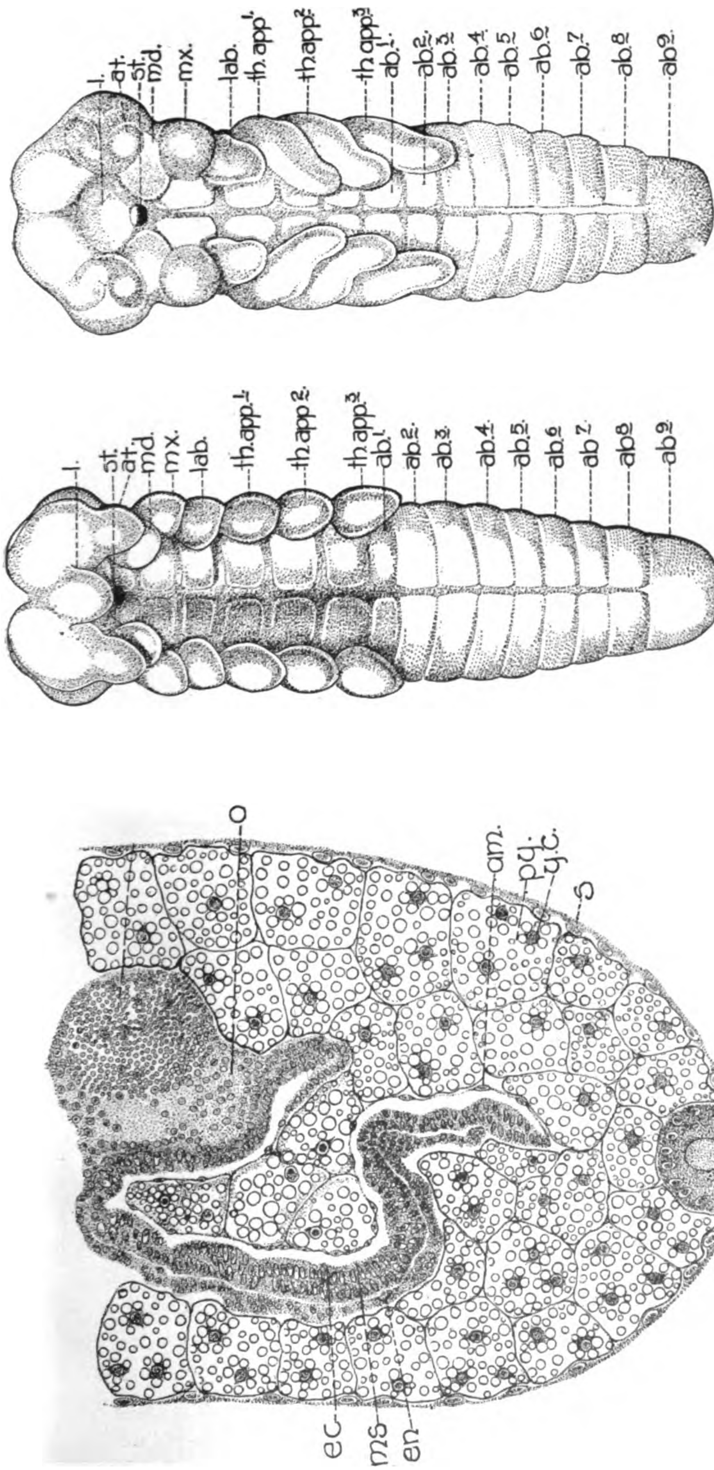
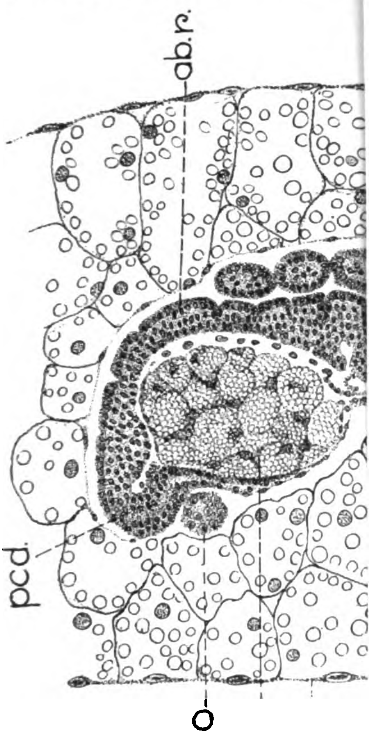



DEVELOPMENT OF THE EMBRYO IN THE EGG OF TOXOPTERA GRAMINUM.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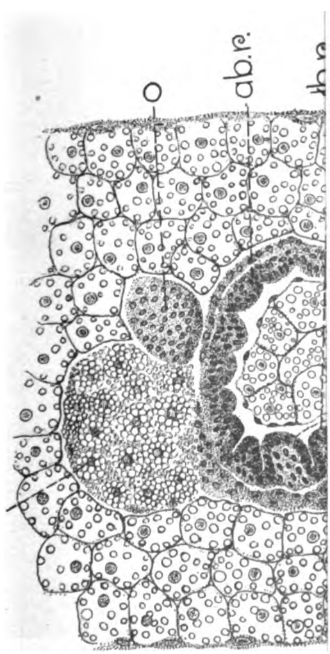
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In *Stage 8* (Pl. VI, fig. 2) the posterior or abdominal region of the embryo has now completely changed its position, having folded back dorsally about the ovarian yolk. Plate VI, figure 2, shows a sagittal (slightly oblique) section of an embryo at this stage. There are apparently only 9 abdominal segments. Both the stomodæum and the proctodæum are plainly in evidence now, and the mesenteron is in course of formation. The latter is formed above and rests upon the ovarian yolk. This yolk now has a granular appearance, and the yolk cells within it appear to be breaking down. It is still divided off into subspherical masses. The polar organ is smaller than in the preceding stage and the pear-shaped area in the center is filled with a yellowish substance as before. The ovaries are represented in this section by a circular mass of cells above the ovarian yolk. The primary yolk is grouped and divided off by protoplasmic threads, very much as in the preceding stage, but is not quite so abundant now. Plate V, figure 3, shows a surface view of the embryo, straightened out to its full length. It will be seen that the appendages are now much more elongate, the thoracic appendages showing traces of segmentation. All the appendages are now directed posteriorly and lie flat upon the body.

This is the stage in which the majority of the embryos pass the winter. It is very doubtful if any of the stages earlier than the seventh are able to survive the winter. Instances have come under our observation in which embryos in the sixth stage have been killed by very low temperatures. When heavy freezes do not occur until sometime in December, a very large percentage of the eggs hatches; on the other hand, however, when heavy freezes begin in November, large numbers of the eggs are killed in the early stages, since large numbers of the eggs are deposited in this month. An early autumn, therefore, followed by a severe winter, would limit to a great extent the number of stem mothers of the following spring.

*Stage 9* (Pl. VII, figs. 1–4) represents the stages of growth occurring in the latter part of February and the first of March. When the embryo is ready to come to the surface of the egg (Pl. VII, fig. 1), it moves forward in the yolk until the cephalic lobes come into contact with the polar organ. It will be observed that there is quite a gap between figures 1 and 2, and at present we have no material from which this missing link can be supplied. Figure 2 shows the dorsal organ already formed. As we have no intermediate stages we can not state definitely whether this is the true dorsal organ or the dorsal and polar organ combined. It is probably the latter, as we do not find any traces of the polar organ at any other point in the embryo. It is very probable that the surplus cells of the serosa, at the time the embryo comes to the surface of the egg, collect at and group themselves about the polar organ, as there

appear to be a greater number of cells about this body at this time. There is no trace of the dense yellowish center of the polar organ, otherwise it resembles this body very closely. However, as we have lost track of this organ in the gap between figures 1 and 2, and on account of the close resemblance between it and the dorsal organ of other insects, we have designated it as the latter. At a later stage (Pl. VII, fig. 3) the dorsal organ has assumed a more nearly circular shape, the mouth having almost closed, inclosing a somewhat pear-shaped space. At a still later stage (fig. 4) the dorsal organ has released itself from the margin, migrated backward, and begun to disintegrate. At length it disappears by absorption in the body cavity.

At first we were not able to note a revolution of the embryo, but later studies show that such a revolution does occur between figures 1 and 2 of Plate VII.

After the ninth stage the development goes on very rapidly, and by the latter part of March the eggs are ready to hatch.

During the fall of 1909 a number of eggs were collected that had been deposited in October and November, and these were kept until the spring of 1910 to note the time of hatching. No heavy freezes occurred until the 3d of December. It was found that although there was nearly a month's difference in dates of deposition there was not more than four or five days' difference in the time of hatching. An average of 64 per cent of the eggs hatched. We have also learned that eggs will not hatch unless subjected to freezing temperatures.

## SUMMARY OF EMBRYOLOGICAL DEVELOPMENT.

There is a large almost circular mass of ovarian yolk at the posterior pole of the egg.

Development begins almost immediately after oviposition, and proceeds more rapidly in the region of the anterior pole until after the blastoderm forms, after which growth almost ceases in this region.

The blastoderm originates through the migration of yolk cells from the interior to the surface of the egg. All of the yolk cells, however, do not take part in the formation of the blastoderm, part remaining behind to prepare the yolk for assimilation by the embryo.

After the blastoderm is formed it is one cell thick and covers the entire surface of the egg, with the exception of the ovarian yolk. The germ band originates in the region of the ovarian yolk, where it invaginates and grows downward into the egg. The germ band is of the completely submerged type, the uninvaginated blastoderm becoming the serosa.

Upon leaving the surface of the egg the germ band leaves behind it a group of cells embedded in a mass of protoplasm. This body the junior author has termed the "polar organ."

The development of the embryo can be observed in a general way, with a hand lens, up to and including the sixth stage. This stage is reached, under favorable weather conditions (50° to 75° F.), in about three days.

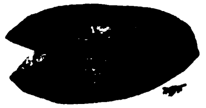

FIG. 18.—The spring grain-aphis: Shell of egg after young stem-mother has emerged. Greatly enlarged. (Original.)

A large number of embryos are nearly or quite half grown by the time freezing weather begins, growth starting again with the first warm days of February. We have noted a revolution of the embryo within the egg, and this revolution takes place between figures 1 and 2 of Plate VII. Eggs begin to hatch by the last week in March, the typical appearance of the abandoned eggshell being shown in text figure 18. The number of stem mothers to appear in spring depends to a large extent upon the temperature of the preceding fall.

ABBREVIATIONS USED IN PLATES III–VII.

*A.*, anterior pole.
*ab*[1], *ab*[2], etc., abdominal segments.
*ab. r.* abdominal region.
*am.*, amnion.
*app.*, appendage.
*at.*, antenna.
*b. c.*, blastoderm cell.
*b.*, blastoderm.
*c. l.*, cephalic lobes.
*d. o.*, dorsal organ.
*ec.*, ectoderm.
*en.*, entoderm.
*g. b.*, germ band.
*l.*, labrum.
*lab.*, labium.
*md.*, mandible.
*ms.*, mesoderm.
*mx.*, maxilla.
*o.*, fundament of ovary.
*o. y.*, ovarian yolk,
*p.*, posterior pole.
*p. o.*, "polar organ."
*p. p.*, peripheral protoplasm.
*p. y.*, primary yolk.
*pcd.*, proctodæum.
*s.*, serosa..
*s. g.*, salivary gland.
*st.*, stomodæum.
*th. app*[1], [2], etc.,thoracic appendages.
*th. r.*, thoracic region.
*y. c.*, yolk cells.

## NATURAL ENEMIES.

*Toxoptera graminum* is beset by a host of foes, without which we would be powerless to combat it. These enemies naturally group themselves into two classes: First, insects that develop within the body of the "green bug" and are termed true parasites; secondly, those foes that feed upon them externally or that take them directly into their bodies. These latter are termed predatory enemies. Under the true parasites we have *Aphidius testaceipes* Cress., *Aphidius avenaphis* Fitch, *Aphidius confusus* Ashm., *Aphelinus mali* Hald., *Aphelinus nigritus* How., and *Aphelinus semiflavus* How., all of which are minute four-winged flies; under predatory enemies there are lady-beetles, syrphids, and cecidomyiids (two-winged flies), lacewing flies, and birds. Besides these, there are *secondary* parasites, or those that prey upon the true parasites of Toxoptera. These latter are as truly our enemies as are Toxoptera.

## INTERNAL OR TRUE PARASITES.

### Aphidius testaceipes Cress.

(Fig. 19.)

Synonyms: *Lysiphlebus abutilaphidis* Ashm.; *Lysiphlebus baccharaphidis* Ashm.; *Lysiphlebus basilaris* Prov.; *Lysiphlebus citraphis* Ashm.; *Lysiphlebus coquilletti* Ashm.; *Lysiphlebus cucurbitaphidis* Ashm.; *Lysiphlebus crawfordi* Rohwer; *Lysiphlebus eragrostaphidis* Ashm.; *Lysiphlebus gossypii* Ashm.; *Lysiphlebus myzi* Ashm.; *Lysiphlebus minutus* Ashm.; *Lysiphlebus persicaphidis* Ashm. (=*L. persiaphidis* Ashm.); *Lysiphlebus piceiventris* Ashm.; *Lysiphlebus tritici* Ashm.

DESCRIPTION AND IDENTITY.

*Female.*—Piceous or shining black, smooth and polished, impunctured; mandibles and palpi pale; antennæ brownish-black, sometimes more or less pale beneath,

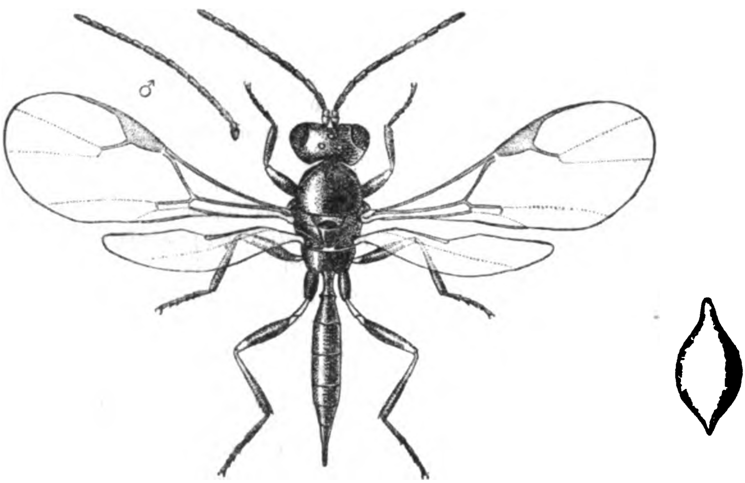


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FIG. 19.—*Aphidius testaceipes*, principal parasite of the spring grain-aphis: Adult female and antenna of male, greatly enlarged. Egg at right, highly magnified. (From Webster.)

13-jointed, the joints faintly fluted or grooved, the last one longest and thickest; wings hyaline, iridescent, stigma pale; legs, including coxæ, yellowish-testaceous, the posterior pair generally more or less fuscous or blackish; abdomen often brown or pale piceous, with the first and sometimes part of the second segment more or less testaceous. Length, 0.07 inch.

*Habitat.*—Rockledge, Fla.; Selma, Ala.; and Pocomoke City, Md.

Parasitic upon an aphidid infesting twigs of orange, an aphidid on the cotton plant, and *Aphis avenæ* Fab.

This parasite, which is probably the most important of all the natural enemies of Toxoptera, has for this reason claimed more of our attention than all of the other foes combined. Hence a large amount of data has been collected, bearing upon nearly every phase of its development. Owing to the fact that large numbers of individuals have been reared by Messrs. Kelly and Urbahns from known par-

ents, both parent and offspring being preserved, Mr. H. L. Viereck, of this bureau, has been able to determine definitely for us the identity of this species and to clear up the obscurity heretofore surrounding it. He finds that it has been masquerading under 14 different names, and it seems that it may now be allowed to assume its rightful designation.

Mr. Viereck, after a careful study of all material at hand, has supplied us with the above list of synonyms. His work on the revision of the genera Aphidius, Lysiphlebus, and Diæretus will appear later in some other publication.

## LIFE HISTORY.

### OVIPOSITION.

Under favorable conditions the females begin ovipositing within a few hours after issuing, whether a male is present or not. When the female is placed in the presence of Toxoptera she will rush about

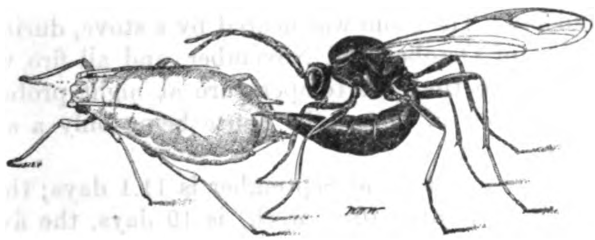

FIG. 20.—*Aphidius testaceipes* ovipositing in the body of the spring grain-aphis. Enlarged. (From Webster.)

in an excited manner and when her antennæ come in contact with an aphis she stops very quickly and thrusts her abdomen beneath her thorax and head (see fig. 20), giving the aphis a quick stab—sometimes several if the first attempts were unsuccessful; she oftentimes lifts the smaller plant-lice completely from the leaf, they are stabbed so fiercely. The act of oviposition shown in the illustration is not intended to convey the impression that the Aphidius always attacks the grain aphis at this point, as it will stab it from any position; it will oftentimes reach around the margin of a leaf and pierce an aphis on the opposite side. After being stung the aphidids kick up the posterior part of the abdomen as though in pain, and sometimes a tiny drop of fluid will appear at the tip of the cornicles. At no stage do the aphidids appear to be exempt from attack. The Aphidius readily attacks the winged, but apparently prefers the wingless forms.

If parasites are confined with plant-lice for quite a while they will stab them repeatedly, though we have never reared more than one individual from the body of an aphis. It is very probable that in cases of this kind it is the survival of the fittest, the strongest Aphidius larva devouring all of the others. The junior author and Mr. W. R.

Walton, of this bureau, observed a larva, taken from the body of a "green bug," to apparently feed upon another larva of the same species that was resting against it. This would seem to indicate a tendency toward cannibalism. The parasites have been observed apparently ovipositing in aphidids that were already dead from parasitic attacks, those killed by fungus, and sometimes even puncturing the leaves of the plants on which Toxoptera were located.

The period of oviposition varies from 3 days to a week or more, depending upon the temperature. In warm weather the females will easily live and oviposit for 5 or 6 days.

### LENGTH OF PERIOD FROM EGG TO ADULT.

Messrs. Kelly and Urbahns found that at Wellington, Kans., from 7 to 15 days are consumed in passing from egg to adult during August and September, while for October and the first week in November it requires from 8 to 24 days. These figures are to a slight degree artificial, as the rearings upon which they are based were conducted indoors. The room was heated by a stove, during the day only, for a part of October and November, and all fire was extinguished at night, so that the temperature at night probably went almost as low as out of doors, the house being only a small two-room structure.

The average for August and September is 11.1 days; the average for October and November (first week) is 19 days, the average for the whole period being 15.9 days. These averages were made up from observations on 116 individuals and are therefore of more value than they would be if made from a few individuals only.

At Richmond, Ind., the period from egg to adult out of doors varies from 10 to 14 days during August and September, while Toxoptera that were parasitized during November of 1907 and kept out of doors did not give up adults until the 27th and 28th of March and the 4th of April, 1908, a period of over 4 months.

### EFFECT OF PARASITISM BY APHIDIUS UPON DEVELOPMENT OF HOST.

It has been found, as previously stated, that at no time from birth to and including the adult stage is Toxoptera exempt from attack by Aphidius. It appears that a female Aphidius prefers to oviposit in Toxoptera of the second and third instars. The parasite apparently shows little or no fear of them at this stage, while if she is among a number of adult Toxoptera and they begin to kick up their abdomens, she often hurries away, apparently in alarm.

It appears from our observations that Toxoptera stung before the first or second molt will not reach maturity, nor will the developing parasite become adult, there being apparently insufficent nourishment contained in such small individuals. Aphidids parasitized after

the second molt will become adult, but may be either winged or wingless; the wings in such cases often being imperfect. Oftentimes parasitized aphidids reach the third molt, but do not become adult before death, though the parasite reaches maturity, and it is probable that such Toxoptera were parasitized just before casting the second molt. This may also account for some of the small individuals among the parasites.

### EFFECT OF PARASITISM BY APHIDIUS UPON FECUNDITY OF HOST.

Experiments have been conducted with the view of learning the number of young that may be produced after parasitization. This can probably be best illustrated by Table XII.

TABLE XII.—*Effect, on fecundity of Toxoptera graminum, of parasitization by Aphidius testaceipes.*

| Number of individuals. | Stage when parasitized. | Date parasitized. | Kind of adult. | Daily number young. | | | | | | | | | | Total young. | Date aphis died. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Oct. 15. | Oct. 16. | Oct. 17. | Oct. 18. | Oct. 19. | Oct. 20. | Oct. 21. | Oct. 22. | Oct. 23. | Oct. 24. | | |
| 1 | Fourth instar | Oct. 15 | Winged | | A. | | | 6 | | | | | | 6 | Oct. 24 |
| 1 | do | Oct. 16 | do | | | A. | 6 | 3 | | | | | | 9 | Do. |
| 1 | Wingless adult | do | Wingless | | | | 2 | 3 | 1 | | | | | 6 | Do. |
| 1 | do | do | do | | | | 4 | 4 | 2 | | | | | 10 | Oct. 27 |
| 1 | do | do | do | | | 2 | 1 | 2 | | | | | | 5 | Oct. 20 |

| Number of individuals. | Stage when parasitized. | Date parasitized. | Kind of adult. | Daily number young. | | | | | | | | | | Total young. | Date aphis died. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Mar. 15. | Mar. 16. | Mar. 17. | Mar. 18. | Mar. 19. | Mar. 20. | Mar. 21. | Mar. 22. | Mar. 23. | Mar. 24. | | |
| 1 | Fourth instar | Mar. 17 | Winged | | | | | | A. | 2 | | | | 2 | Mar. 25 |
| 1 | do | do | do | | | | | | A. | 4 | | | | 4 | Do. |
| 1 | do | do | do | | | | A. | | 6 | 2 | | | | 8 | Do. |
| 2 | do | do | do | | | | | | A4 | 7 | | | | 11 | Do. |
| 2 | do | do | do | | | | | | A1 | 10 | 3 | | | 14 | Do. |
| 6 | do | do | do | | | | | | A1 | A16 | 9 | | | 26 | Do. |
| 9 | Winged | do | do | | | | 1 | | 38 | 21 | 2 | | | 61 | Mar. 26 |
| 4 | Fourth instar | do | Wingless | | | | A. | | A9 | 34 | | | | 43 | Do. |
| 5 | Third instar | do | Winged | | | | M. | | M1 | | A2 | | | 3 | Do. |

A.=Adult. M.=Molt.

Two adult Aphidius issued from those individuals included in the first section of the table and 18 from those in the last section. In this latter section Aphidius began to issue March 30 and the last issued on April 3. Those that issued on the latter date were from those that were adult winged adults when parasitized.

All of these experiments were conducted indoors, and those of the last division of Table XII, under a daily temperature ranging from 50° to 80° F.

From Table XII it will be seen that Toxoptera that have molted only twice before being parasitized may become winged adults, and in some instances produce young. All of our observations show that individuals that have molted three times and then been parasitized will become adult and produce young, and in case they are wingless they may produce 10 or more. Eleven is the maximum number of young, according to our observations, produced by a single individual after parasitization.

### MOVEMENT OF LARVA WITHIN THE HOST AND MANNER OF ATTACHING IT TO THE PLANT.

Observations were made upon the movements of the larva (fig. 21) within the host by the senior author at Manhattan, Kans., in 1907, and published in the Proceedings of the Entomological Society of Washington.[1]

It appears that the larva of the parasite, at least until after it attains some growth, moves little if at all within the body of the host, and thus interferes with no vital functions of the Toxoptera.

When the larva nears maturity, as shown by the yellowish color of the abdomen of the "green bug," it becomes quite active, making a number of revolutions within the body of its host, at which time the latter seizes the leaf with a rigid death-grip and the last spark of life soon fades. The object of the revolutions is, apparently, to mold the body wall of the aphidid, while it is still plastic, into the most suitable shape for pupation. An idea of how this desired end is accomplished may be obtained by glancing at the accompanying illustrations. Figure 22 shows the normal position of the parasitic larva within the body of the host before the revolutions begin. It was found that a fully developed larva (fig. 23) made three revolutions within the body of the host, always going forward, in the space of 35 minutes. During the next 5 minutes it made another revolution; a fifth revolution was completed in the next 10 minutes; the sixth during the following 8 minutes; the seventh in the next 9 minutes; the eighth after a space of 4 minutes; the ninth in the following 4 minutes, after which, on account of the opaqueness of the walls of the host, no further count was kept of the revolutions, although several more were known to have been made. Some of these different positions of the larva and

[1] Proc. Ent. Soc. Wash., vol. 9, Nos. 1-4, pp. 110-114, 1907.

the shapes the body of the Toxoptera assumes are graphically represented in figure 21. At this time, or about one and one-half hours

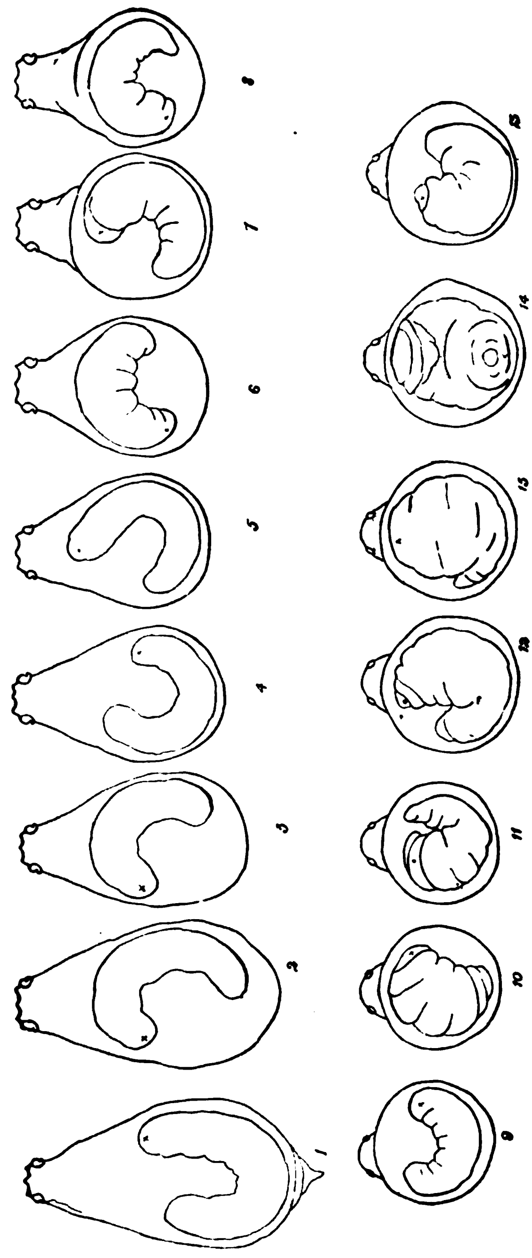

FIG. 21.—(1) Position of larva of *Aphidius testaceipes* in body of wingless adult female of the spring grain-aphis, just before beginning its revolutions for fashioning the body of the aphis into a pupal envelope, 11 a. m. (2–7) Some of the positions assumed by the Aphidius larva between 11 a. m. and 11.35 a. m., during which time it made three complete revolutions. (8–9) Positions during and at completion of eighth revolution, 12.11 p. m. (10) Position at completion of ninth revolution, showing contraction of the larva, 12.15 p. m. (11) Position at 12.20 p. m. (12) Position at 12.22 p. m. (13) Position at 12.27 p. m. (14) Position at 12.32 p. m. (15) Position at 12.32½ p. m. (From Webster.)

after the observations were begun, the body wall of the "green bug" became quite dark and almost globular in form, and this shape it afterwards retained.

Mr. Kelly, of this bureau, later took up the observations at this point, during the fall of 1908, and published the results of his obser-

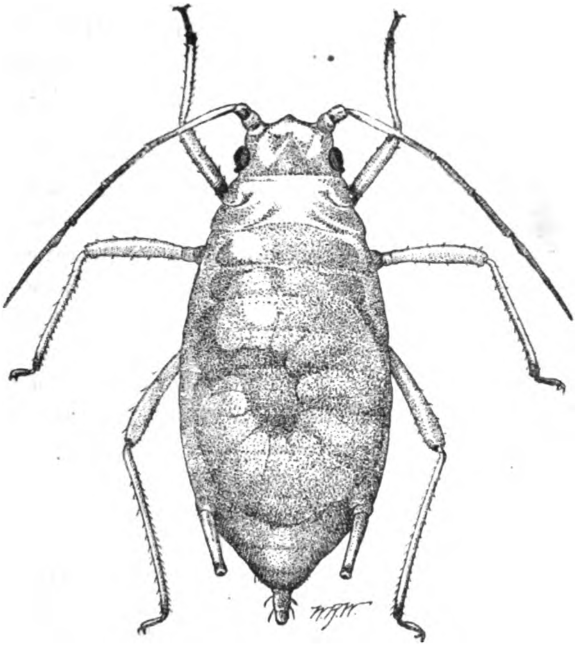

FIG. 22.—Position of larva of *Aphidius testaceipes* in the body of the spring grain-aphis at the beginning of the change to a yellowish color. Much enlarged. (Original.)

vations in the Proceedings of the Entomological Society of Washington.[1] Mr. Kelly confined some aphidids that were nearly dead from parasite attack on a slide and observed them under the microscope. He found that as the body of the "green bug" takes on a brownish tint, the Aphidius larva within makes a longitudinal slit or opening in the ventrum and enlarges it until it is more or less oval in shape, as shown in figure 24.

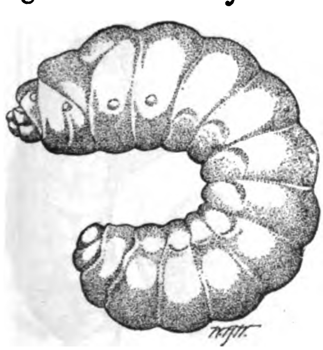

FIG. 23.—Full-grown larva of *Aphidius testaceipes* taken from body of the spring grain-aphis as shown in figure 22. Much enlarged. (Original.)

The rigid, firm manner in which Toxoptera grasps the object upon which it is resting at death apparently has the effect of holding it in place while the movements of the parasitic larva are going on within. When the opening is complete the larva begins to spin its cocoon, at the same time ejecting a glutinous fluid that makes the strands adhere to any object

[1] Proc. Ent. Soc. Wash., vol. 11, No. 2, pp. 64–66, 1909.

with which they come in contact. The body of the aphidid is cemented firmly to the object upon which it finally comes to rest. The inner abdominal walls of the plant-louse are also lined with silk, which firmly adheres to them, and it may be that the silk also acts as a tanning substance for the body of the aphidid, as the latter becomes leathery and is apparently impervious to water; the old leathery bodies of the plant-lice may often be found firmly attached to plants after a heavy rain. After the cocoon is completed the larva becomes quiet and in most cases assumes, according to the junior author, a position directly opposite to that which it assumed while feeding and developing. Figure 22 shows a larva feeding, however, in the reversed position; this seems to be unusual, the normal position being as shown in Figure 21, *l*. The larva oftentimes, on becoming fully developed, is in some way dislodged from the body of the aphidid. This is probably due to some interference while attaching the host to the leaf. These cases are quite numerous in badly infested fields and the larvæ apparently never become adult. Figure 25 is a graphic illustration of one of these accidents.

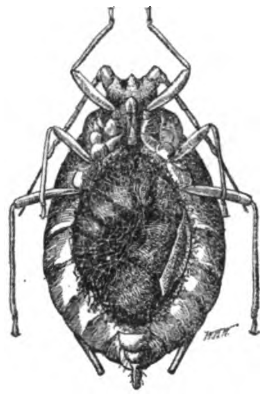

FIG. 24.—Larva of *Aphidius testaceipes* spinning its cocoon in the dead body of the spring grain-aphis, showing the slit or opening in walls of underside of host insect. Much enlarged. (Original.)

Mr. Kelly found that the pupal stage lasted from 3 to 4 days.

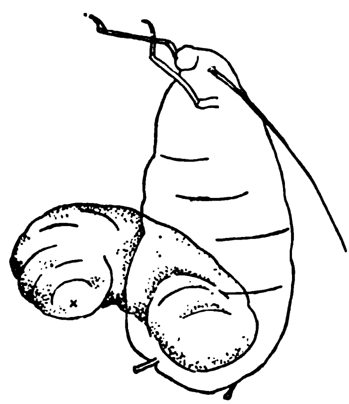

FIG. 25.—Larva of *Aphidius testaceipes* working its way prematurely from the body of the spring grain-aphis. (From Webster.)

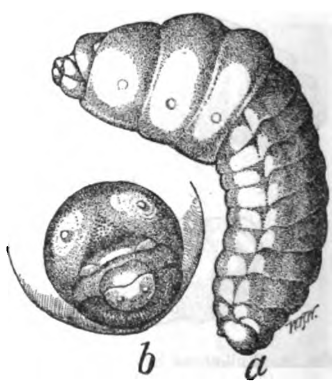


FIG. 26.—Full-grown larva of *Aphidius testaceipes*: *a*, Lateral view just prior to pupation; *b*, front view of head. Greatly enlarged. (Original.)

Figure 26 shows the larva just prior to pupation. These observations were made indoors, during the winter, at the ordinary room temperature. It requires from 3 to 5 hours for the Aphidius to

emerge as an adult after the first movements of the pupa begin, and when ready to issue the pupa expands and contracts the abdomen, moving the feet and antennæ until these are freed from their gum-like covering. Upon studying the pupæ (fig. 27) closely, we find that the prothorax bears two rows of distinct elevations or tubercles, but we have been unable thus far to ascribe any particular function to them and they disappear with the gum-like covering. The junior author finds that the adult gradually works itself about until it gets in a position with its back to the ventrum of the old aphidid shell, when it cuts a circular hole, as described by Mr. Kelly, and crawls out, always with its head pointing toward the head of the old aphidid. Figure 28 represents an old dead body of a "green bug" after the parasite has issued.

FIG. 27.—Pupa of *Aphidius testaceipes* immediately after pupation. Much enlarged. (Original.)

FECUNDITY.

From the prompt manner in which Aphidius, under favorable weather conditions, overcomes Toxoptera it will readily be seen that the former must be a very prolific breeder. The average adult female contains from 4 to 450 eggs. These eggs are lemon-shaped (see fig. 19), very pale, and translucent.

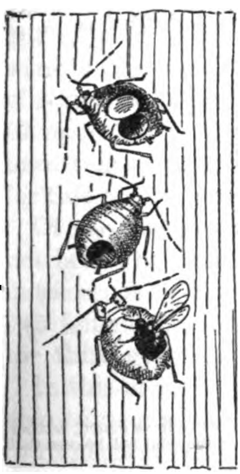

FIG. 28.—Dead "green bugs" (*Toxoptera graminum*), showing holes from which the matured parasites of *Aphidius testaceipes* emerge. The top figure shows the lid still attached, but pushed back; the bottom figure shows the parasite emerging. Enlarged. (From Webster.)

Messrs. Kelly and Urbahns conducted a number of experiments at Wellington, Kans., in 1908, to determine the number of offspring produced by one individual. They found that one Aphidius would parasitize as many as 206 Toxoptera. In their experiments, however, they used only a few more than 200 Toxoptera to each individual. Mr. Parks, at the same place in 1909, conducted 16 experiments, using from 300 to 500 Toxoptera and he had a maximum, in one case, of 301 aphidids parasitized from one individual Aphidius. His minimum was 3; his next highest number was 33, and his next was 44. Of the sixteen, 12 fell below 100; his average was 94.6.

Mr. Parks also conducted experiments at the same time as the above to ascertain what the effects of continuous mating of one male to different females would have on the offspring. In this experiment 1 male was mated to 12 unfertilized females within a period of two hours, after which each female was placed in a separate cage with about 100 Toxoptera that had not been exposed to Aphidius.

The male refused to mate with any more females after the twelfth. Table XIII shows the results of these observations:

TABLE XIII.—*Offspring produced as the result of mating one male Aphidius with 12 females.*

| Female, cage No.— | Female mated with male from cage No.— | Offspring. | |
|---|---|---|---|
| | | Males. | Females. |
| 180 | 180 | 29 | 55 |
| 181 | 180 | 14 | 33 |
| 182 | 180 | 21 | 30 |
| 183 | 180 | 35 | 41 |
| 184 | 180 | 2 | 8 |
| 185 | 180 | 0 | 0 |
| 186 | 180 | 13 | 30 |
| 187 | 180 | [illegible]9 | 25 |
| 188 | 180 | 1 | 0 |
| 189 | 180 | 50 | 0 |
| 190 | 180 | 8 | 9 |
| 191 | 180 | 26 | 16 |

From these data it appears that all of the eggs from the last few females were not fertilized, as Mr. Kelly finds that females predominate when the eggs are properly fertilized. Table XIV illustrates this latter point.

TABLE XIV.—*Offspring of Aphidius produced from eggs properly fertilized.*

| Cage No.— | Offspring. | |
|---|---|---|
| | Males. | Females. |
| 197 | 39 | 67 |
| 297 | 15 | 20 |
| 299 | 13 | 33 |
| 300 | 24 | 40 |
| 302 | 20 | 34 |
| 304 | 16 | 50 |
| 306 | 47 | [1]2 |
| 333 | 115 | [1]5 |
| 403 | 26 | 41 |
| 404 | 38 | 93 |
| 405 | 26 | 44 |
| Total.. | 379 | 429 |

[1] These two females were apparently unfertilized, although they were supposed to have mated, as they give about the same results as some of the unmated females. If these two be eliminated it will be seen that the females are far in excess of the males.

## PARTHENOGENESIS.

In all of the studies of parthenogenesis care was taken to preserve both parents and offspring, the individuals of each family or brood being preserved and kept entirely separate for future systematic studies, which were later carried out by Mr. Viereck.

The first record of parthenogenesis of this species was published in the Proceedings of the Entomological Society of Washington,[1] by the junior author, whose attention was first called to this phenomenon

[1] Proc. Ent. Soc. Wash., vol. 10, Nos. 1-2, September 15, 1908, pp. 11-13.

during the summer of 1907, while making observations on the life history of the species; hence, a series of experiments was begun in order to learn something definite in regard to it. Seven female Aphidius were selected, just as they issued from their cocoons (being therefore unfertilized), and placed in separate cages with 30 to 40 Toxoptera not previously exposed to parasite attack. All of the parasites began ovipositing at once. After one of the females had apparently parasitized all of the aphidids in her cage she was mated and placed in a second cage with a number of Toxoptera as before. All the offspring from unmated females were males, but the offspring from the single female, *after she had mated*, comprised 22 females and 4 males.

Messrs. Kelly and Urbahns elucidated this phenomenon more fully during the summer of 1908 at Wellington, Kans.[1] These experiments were conducted as follows:

Starting with a mated female, the females from among her offspring were isolated, even before emergence. On their appearance they were given Toxoptera not previously exposed to parasitic attack. The few females from among this second generation were again isolated in the same manner, the females in all cases being kept unmated. Nearly 100 experiments were conducted in this manner, but only 48 gave results. The offspring of 44 out of the 48 isolated were, all of them, males. Of the 4 remaining females, the offspring of 3 were as follows: 70 males and 3 females; 101 males and 6 females; 67 males and 1 female. In the case of the remaining female, some uncertainty exists as to whether she had been fertilized or not, and, for this reason, a census of her offspring is not here included.

Of the three exceptional cases the offspring from one female were not bred any further; from a second, the offspring became all males in the second generation; the offspring from the third female produced two females in the second generation, all finally becoming males in the third generation.

In this manner it will be seen that Messrs. Kelly and Urbahns were able to rear a limited number of females parthenogenetically to the third generation. Beyond this all of the offspring were males. While the conditions under which these experiments were conducted would not obtain under ordinary field conditions where the infestation was great, it could very easily occur where there are very few aphidids present. This apparently abnormal feature, then, would greatly assist the species in tiding over periods of scarcity of plant-lice.

### HOSTS OF APHIDIUS TESTACEIPES.

Since we were able to find *Aphidius testaceipes* over almost the entire United States, it seemed clear to us that it must have hosts other than *Toxoptera graminum.* Accordingly Messrs. Kelly and Urbahns con-

[1] Ann. Ent. Soc. Amer., vol. 2, No. 2, 1909, pp. 67-87.

ducted about 200 experiments in order to gain some definite information on this point. Their mode of procedure was to search out different species of parasitized aphidids in the fields, rear the adult parasites, and breed them into *Toxoptera graminum;* then, if possible, breeding them again into the original host. One attempt, if unsuccessful, was not considered sufficient, several trials being made. While conducting these experiments, other species of parasites were found that would breed into Toxoptera also. These will be dealt with in their proper places. In all of these breedings, both parent and offspring were kept separate and preserved for future study.

It was found that *Aphidius testaceipes* would breed interchangeably from Toxoptera into *Aphis setariæ, Aphis maidis, Aphis middletoni* Thos.,[1] *Aphis gossypii,* and a species of Chaitophorus. This is the same as the list published by the senior author in the Annals of the Entomological Society of America,[2] with the exception that Chaitophorus is added and *Aphis brassicæ* has been expunged from the list, as it has been learned that the species of parasite that would interchange with *Toxoptera graminum* and *A. brassicæ* is another species of Aphidius.

Besides the above list of interchangeable breedings, *Aphidius testaceipes* has been reared from *Aphis œnotheræ* at Salisbury, N. C., by Mr. R. A. Vickery; from *A. medicaginis* at Wellington, Kans., by Messrs. Kelly and Urbahns; from *A. rumicis* at Clemson, S. C., by Mr. G. G. Ainslie; from *Macrosiphum viticola* at Wellington, Kans., by Mr. Kelly; from *M. granaria* at Spartanburg, S. C., by Mr. G. G. Ainslie; from *Melanoxantherium* sp. at Leavenworth, Kans., by Mr. Kelly; from *Macrosiphum* sp. on black gum (*Nyssa sylvatica*) at Salisbury, S. C., by Mr. Vickery; from *Aphis avenæ,* at Salisbury, N. C., by Mr. Vickery; at Leavenworth, Kans., by Mr. Kelly, and at Washington, D. C., by Mr. C. N. Ainslie; and from *Aphis medicaginis* by Mr. J. T. Monell, at St. Louis, Mo. *Aphidius testaceipes* has also been reared from several unidentified species of aphidids, as follows: From an aphidid on *Ampelopsis* sp. by Mr. C. N. Ainslie; from an aphidid on *Capsella* sp. at Wellington, Kans., by Mr. C. N. Ainslie; from an aphidid on *Kochia scoparia* at Rochester, Minn., by Mr. C. N. Ainslie; from an aphidid on locust at Wellington, Kans., by Mr. Kelly; from an aphidid on plum at Salisbury, N. C., by Mr. Vickery; from an aphidid on pigweed (*Chenopodium album*) in Olmstead County, Minn., by Mr. C. N. Ainslie.

Further addition to this list of hosts may be made by citing the hosts of some of the synonyms of *Aphidius testaceipes.*[3] We will deal

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[1] *Aphis middletoni* can not be satisfactorily separated from *Aphis maidi-radicis* and when found on any other plant except Erigeron it has usually been identified as *Aphis maidi-radicis.* (See Bul. 85, Bur. Ent., U. S. Dept. Agr., pp. 113-114. Contributions to a Knowledge of the Corn Root-Aphis, by R. A. Vickery.)

[2] Ann. Ent. Soc. Amer., vol. 2, No. 2, pp. 67-87, June, 1909.

[3] See Proc. U. S. Nat. Mus., vol. 11, pp. 665-669, 1888.

with these synonyms collectively under *A. testaceipes*. The hosts then would be as follows: Reared from *Macrosiphum cucurbitæ* by the senior author at Lafayette, Ind.; reared from an aphidid on *Eragrostis* sp., by Mr. D. W. Coquillett; reared from *Macrosiphum* sp. on *Audibertia stochoides*, by Mr. Coquillett, at Los Angeles, Cal. Swept from *Eragrostis* sp. by the senior author at La Fayette, Ind., October 4, 1885; reared from *Myzus* sp. on *Hosackia glabra* by Mr. Coquillett at Los Angeles, Cal.; reared from *Myzus ribis* (currant aphis) by Prof. A. J. Cook, Lansing, Mich.; reared from *Aphis gossypii* by Prof. G. F. Atkinson, Columbia, S. C.; reared from *Macrosiphum* sp. on Abutilon by Mr. Coquillett at Los Angeles, Cal.; reared from *Aphis avenæ* by Mr. J. W. Barlow, June 20, 1882, at Cadet, Mo.; reared from Aphis on peach May, 1886, by Mr. Albert Koebele, Fresno County, Cal.; reared from an aphidid on *Baccharis viminalis* by Mr. Coquillett at Los Angeles, Cal.

There are probably many other hosts besides the ones we have mentioned of which as yet we have no knowledge; and when this situation is taken under consideration it is very easy to see that it would be only in rare instances and under peculiar conditions that a locality would be found where *Aphidius testaceipes* would not be lurking, waiting for favorable weather conditions and abundant supplies of its host aphidids to make its appearance in greater or less numbers.

### HIBERNATION.

Aphidius is capable of withstanding extreme degrees of cold, as witnessed by the fact that Toxoptera parasitized during November, 1907, at Richmond, Ind., did not give up adults until the 27th and 28th of March and the 4th of April following. During February they were in the larval stage within an old dead body of a Toxoptera.

Mr. Kelly found that at Leavenworth, Kans., the parasites hibernated as larvæ and pupæ. This was shown by the fact that he found *Aphidius testaceipes* in the field in this condition on November 13, 1907. From a lot of 50 dead parasitized Toxoptera from the same field, that had been washed or rubbed off the leaves of the young grain and were taken out of the mud about the wheat plants on February 28, after the winter was practically over, Mr. Kelly found that 17 contained full-grown larvæ, 12 contained pupæ of a light color, and 21 contained pupæ of a dark color; the latter apparently were ready to develop promptly with the advent of warm weather. Mr. Kelly collected, on the same date and also from this same field, a number of Toxoptera in various stages of development that were hibernating in the fields and which showed no signs of parasitism; the weather had been such as to preclude the possibility of their having recently been parasitized. These were placed in a warm room and soon showed evidence of parasitism, *Aphidius testaceipes* being finally reared from them.

The junior author found that at Richmond, Ind., the adult Aphidius would live for at least two weeks when the temperature was below freezing. The parasites were taken into a warm room several times during these two weeks and they would become active, but when placed out of doors they would soon become numb. These adults were confined, however, so that excessive moisture was excluded, and they may not be able to live for so long a time in the fields unprotected.

The fact that Aphidius can during comparatively cold weather remain for a long period within the body of its host, and the latter give no external visible evidence of its presence, will readily account for the apparent absence of the parasite from any locality for an almost indefinite period; however, when the weather warms up sufficiently for development of the parasite to go on, its presence readily becomes apparent. For these reasons, as well as others that will be mentioned in their proper places, it is impossible to say, from a cursory examination, that Aphidius is not present.

INFLUENCE OF WINDS IN THE DISPERSION OF APHIDIUS TESTACEIPES.

As the natural suppression of an outbreak of Toxoptera is more dependent upon the activity of this parasite than of any other of its natural enemies, it is important to learn the extent to which the parasite is able to follow its host in its spread from the South over the country to the northward.

Dispersion of Aphidius may be accomplished in two ways—first, as larvæ in the bodies of the winged host insect, where it is usually invisible, and, second, by being carried bodily with the winds along with the host.

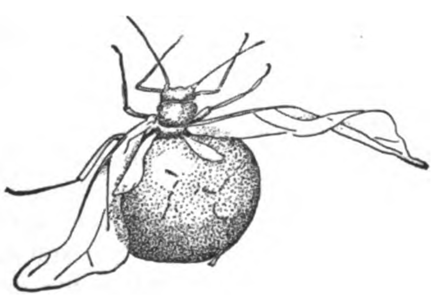


FIG. 29.—Winged female of the spring grain-aphis, parasitized by *Aphidius testaceipes*. Enlarged. (From Webster.)

By referring to Table XII on page 108, it will be observed that a number of cases are there recorded where individuals of *Toxoptera graminum* which were parasitized developed to winged adults, lived for a period of eight or nine days, and during this time gave birth to young, but from their dead bodies Aphidius afterwards issued. The presence of winged parasitized females on the leaves of grain and grasses inhabited by Toxoptera is of common occurrence (see fig. 29). Thus, while it has not been possible to observe the parasitism of individuals and follow out the final dispersion of the same, the evidence tending to show the probability of its general occurrence is so overwhelming that such direct proof does not seem necessary. With the obscurity

relative to this matter cleared away, it will be observed that it is entirely possible for great numbers of the adults, or those that are nearly mature, to become parasitized in a southern locality, the latter to develop to winged females under a more or less high temperature, and for both to be carried many miles to the northward, and then settle down and begin to reproduce, the Aphidius becoming adult and issuing later from the dead body of its host. In the meantime the offspring of the host Toxoptera would, of course, develop and themselves reproduce, some of them, without doubt, falling victims to the very parasite brought along by their parent. While this may not be the chief factor in the dispersion of this parasite, it probably enables it to follow along with the host insect and become diffused with it, although if low temperatures prevail after the time the migrating female settles in her new home there may be considerable delay in the issuing of the adult parasite without to any great extent delaying the development and preventing the increase of Toxoptera.

With the temperature at a point which enables Aphidius to become active there is no doubt that the parasite follows with the host insect, and, indeed, these parasites are usually found on the wing in the company of their hosts during warm sunny days. With high cold winds, which usually come from the northward and would tend to drive the parasites back over territory to which Toxoptera has already come and from which it has now largely disappeared, the adult Aphidius is observed to nestle down among the infested plants and not to venture abroad. Thus it is that this parasite is doubtless usually present in some form in the grain fields with the Toxoptera, though critical examinations of such fields may fail to reveal them until the temperature reaches a point that enables them to become active.

All of this is applicable to the insect in southern territory where no egg stage is yet known to occur. Aphidius occurs all over the country, and we have learned that in the North it winters as fully developed larvæ and pupæ within the "cocooned" bodies of its hosts, its emergence and activity in spring being controlled by the temperature and its dispersion influenced by the same forces and in much the same manner as in the South.

### TEMPERATURE INFLUENCES ON APHIDIUS.

Probably the whole secret of these disastrous outbreaks of Toxoptera lies in the fact that this parasite is not active in a temperature much below 56° F., while, as has already been shown, the aphis begins to reproduce in a temperature at or slightly below 40° F.—a probable difference of at least 16° F. Therefore the situation in a field of wheat in the South in early spring may be described in this way: There are present many Toxoptera of all ages, with viviparous

reproduction continually going on during mild weather. Aphidius may also be present either as invisible undeveloped overwintering larvæ within the living bodies of its host, or it may be present as mature larvæ or pupæ in the dead and dried "cocooned" bodies of the same. Besides this, in the light of recent studies of Aphidius by Mr. Viereck, the same may be true with reference to its occurrence in a considerable number of other common species of aphidids, inhabiting a great variety of vegetation, in the same neighborhood, upon which this same species of Aphidius is parasitic. Thus, it is perfectly clear why, with Toxoptera swarming in the fields, and the parasite present, about 10 days, with the temperature ranging from 40° or 50° to 60° or 70° F., is sufficient to enable the latter summarily to suppress the invasion. The abruptness with which this change is brought about is easily explained by the fact that a parasitized female Toxoptera produces young during only a comparatively few days after being parasitized, although she may survive several days longer, especially if the weather be cool enough to retard the development of the parasite.

In the North the situation is usually quite different, as parasites can not begin their work here to any extent until after the eggs have hatched, and the stem mothers and their offspring have appeared in the fields, thereby furnishing host insects. The overwintering of immature Aphidius larvæ in the bodies of the host is in the North ordinarily precluded by the absence of living host individuals during severe winters, although mature larvæ may winter in the dead bodies of the host as in the South. Stem mothers are probably never present in great numbers and considerable time is therefore necessarily required for their offspring to become excessively abundant. For this reason parasitism, over the section where the host insects pass the winter in the egg, begins later, and, at the start, proceeds necessarily much slower than in the South, but on the other hand Aphidius, unless the winter be an exceptional one, must of necessity winter over in the "cocooned" bodies of its numerous hosts, as mature larvæ or pupæ, and would therefore promptly respond to the warm days of early spring, although delayed somewhat by low temperatures that might not retard the host insects.

There is one point in connection with parasitism by Aphidius that must be always kept in view, particularly to the southward, in order that mistakes and misstatements may be avoided regarding its actual occurrence in any particular locality. While the larva is contained within the still living body of its host its presence there is not easily detected. Indeed it is not until the larva becomes nearly full grown that it can be detected even by an expert. Therefore, in the light of what has previously been stated concerning the situation in milder latitudes, there may be millions of living larvæ

present for weeks in a field with no visible indication of their presence. Yet only a few warm days are required to bring about their final development, whereupon the presence of the more or less globular, leathery, brown bodies of the parasitized host first begin to attract attention and thus actually reveal the presence of the Aphidius, which has already been established there.

An excellent illustration of this is afforded by an occurrence of Toxoptera in eastern North Carolina, observed by Mr. L. M. Smith. In a small field of oats near Newport, wingless viviparous female Toxoptera and young were found in destructive abundance with no indication whatever of the presence of Aphidius. Yet when specimens of the pest submitted by Mr. Smith reached Washington, some of them were beginning to change color from the presence of Aphidius larvæ within their abdomens. Again, when Mr. C. N. Ainslie visited Wellington, Kans., April 1, 1907, he observed no trace of the presence of Aphidius, but upon returning to this same locality on April 10 he found them present. Only a few of the Toxoptera had yet become dark brown, but a large number showed the orange color that told the story of their parasitism. Therefore all statements made in previous publications relative to the lack of parasites, or to the extent to which they occurred in any field or locality, must be understood as applying only to either the adults or to the browned cocooned bodies of the host insects, and are not in any sense to be considered as indicating the extent to which these host insects were carrying obscured Aphidius larvæ about with them in their bodies to develop adults whenever there were a few sufficiently warm days.

### EFFECTS OF WET WEATHER ON THE DIFFUSION OF APHIDIUS.

There is another element affecting the diffusion of this most efficient of natural enemies of Toxoptera, namely, protracted rains. When it is raining the parasite simply will not take wing at all or move about in a way to be affected by winds. This element will not admit of tabulation for the reason that a thunder shower followed by warm, bright sunshine tends to make these, as well as all winged insects, more active after the storm has passed. Thus, the amount of precipitation really means little, while a slow, drizzling, protracted rain (though the total precipitation may be much less) will keep the parasite in seclusion much more effectively. Hence it is that not only a comparatively high temperature accompanied by winds is essential, but the weather must also be fair and sunny.

In British East Africa Toxoptera is worse during seasons when there is much wet weather, and in the Orange Free State outbreaks of the pest seem to be also associated with similar meteorological conditions during spring.

**Other Species of Aphidius.**

*Aphidius confusus* Ashm. has been reared from Toxoptera from different parts of the country, including the Department of Agriculture grounds in Washington, but to what extent it assisted in overcoming Toxoptera in 1907 is not altogether clear. Its life history is apparently similar to that of *A. testaceipes* Cress., and its effect upon the aphides is apparently the same.

*Aphidius avenaphis* Fitch was reared from *Toxoptera graminum* in the insectary at the Department of Agriculture in Washington, the host insect having been parasitized, under observation, by adult virgin Aphidius reared from *Aphis* sp.

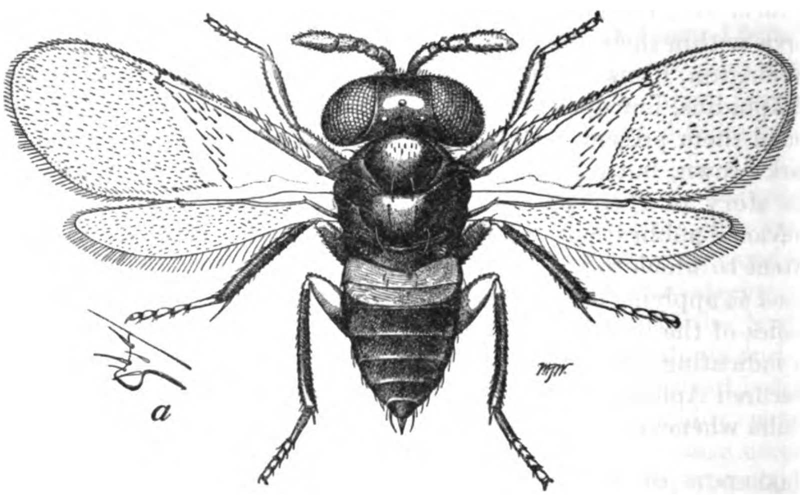



FIG. 30.—*Aphelinus mali*, a parasite of the spring grain-aphis. Greatly enlarged. *a*, Stigmal club, much more enlarged. (Original.)

Species of Aphidius, apparently undescribed, were sent to the bureau from Njoro, British East Africa, and the Orange Free State, South Africa, as enemies of *Toxoptera graminum* in that country.

**Aphelinus.**

We have reared three species of Aphelinus from *Toxoptera graminum; Aphelinus mali* Hald., *A. nigritus* How., and *A. semiflavus* How.

*Aphelinus mali* Hald. (fig. 30) was reared from Toxoptera at Lafayette, Ind., in 1885 by the senior author, by Mr. R. A. Vickery at Richmond, Ind., and from the same species at Clemson, S. C., by Mr. G. G. Ainslie. Messrs. Kelly, Urbahns, and Parks reared it from *Aphis setariæ* Thos. at Wellington, Kans. Messrs. Kelly and Urbahns also reared it from *Schizoneura americana* Riley at Wellington. Mr. Vickery reared it from *Schizoneura lanigera* Haussm. at Richmond,

Ind., and from *Colopha eragrostidis* Middl. at Mt. Vernon, Ind. Mr. Kelly reared it from *Pemphigus fraxinifolii* Riley and from an aphidid taken on *Panicum* sp. Mr. C. N. Ainslie reared it from *Macrosiphum rosæ* Linn., at Mesilla Park, N. Mex.

This species has been previously reared, as stated by Dr. L. O. Howard [1] from *Schizoneura lanigera* Haussm., *Colopha eragrostidis* Middl., *Aphis brassicæ* Linn., *Pemphigus fraxinifolii* Riley, *Aphis monardæ* Oestl., *Macrosiphum rosæ* Linn., *Aphis sacchari* Zehntn., and *Tetraneura colophoidea.*

*Aphelinus nigritus* How. (fig. 31) was first reared from Toxoptera at Spartanburg and Clemson, S. C., by Mr. G. G. Ainslie. It was

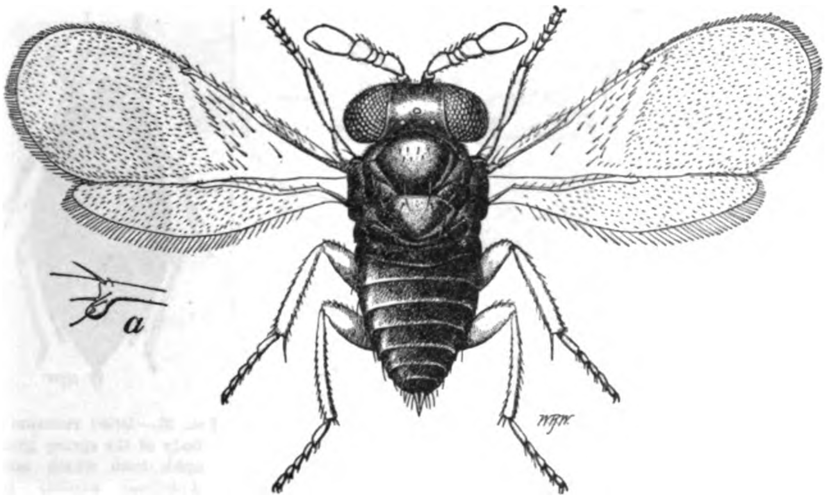



FIG. 31.—*Aphelinus nigritus*, a parasite of the spring grain-aphis. Greatly enlarged. *a*, Stigmal club, still more enlarged. (Original.)

reared from the same species of aphidid by Mr. C. N. Ainslie at Springer and Mesilla Park, N. Mex., and St. Anthony Park, Minn. Mr. T. H. Parks reared it from Toxoptera at Wellington, Kans., and Messrs. Kelly and Urbahns reared it from *Aphis setariæ* Thos. at Wellington.

*Aphelinus semiflavus* How. (fig. 32) was first reared from *Myzus persicæ* Sulz. and *Chaitophorus viminalis* Monell by Prof. C. P. Gillette at Fort Collins, Colo., in 1908. It was later reared by Mr. G. G. Ainslie from Toxoptera at St. Anthony Park, Minn., and from a black aphidid on bluegrass (probably *Rhopalosiphum poæ* Gill.) at Mesilla Park, N. Mex., by C. N. Ainslie.

[1] Ent. News., vol. 19, no. 8, pp. 365–366, 1908.

## NOTES ON LIFE HISTORY AND HABITS OF APHELINUS.

Mr. C. N. Ainslie made some observations on *Aphelinus nigritus* at Mesilla Park, N. Mex., in 1908. He states that when the adult is ready to oviposit it approaches an aphidid very slowly and cautiously, moving or swaying its body slightly from side to side and waving its antennæ. When the antennæ finally touch the plant-louse it stops, turns suddenly about, moves backward slightly, and then gives the victim a thrust with its hairlike ovipositor. This operation apparently causes pain to the aphidid, as she begins to "kick up" her abdomen and there sometimes appears a tiny drop of fluid where the puncture was made.

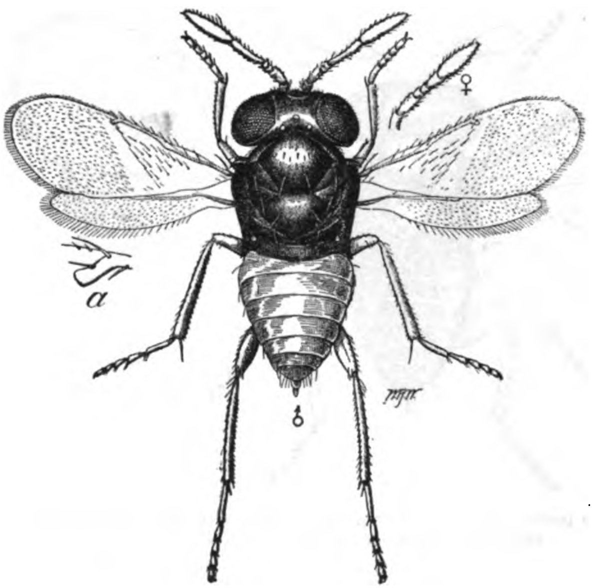



FIG. 32.—*Aphelinus semiflavus*, a parasite of the spring grain-aphis. Greatly enlarged. *a*, Stigmal club, still more enlarged. (Original.)

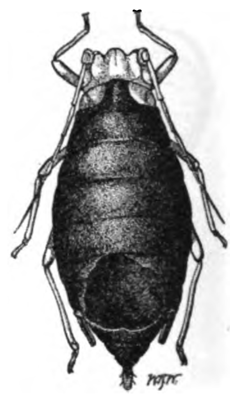


FIG. 33.—Dried remains of body of the spring grain-aphis from which adult *Aphelinus nigritus* has emerged. Enlarged. (Original.)

When the larva of *Aphelinus nigritus* is fully grown the body of the plant-louse, according to Mr. G. G. Ainslie, turns black and the legs a conspicuous white (fig. 33), while in individuals parasitized by *A. mali* these appendages are black. The body, however, of so small an aphidid as *Toxoptera graminum* appears to be but little swollen. Mr. C. N. Ainslie found that under favorable weather conditions *A. nigritus* developed from egg to adult in from 12 to 13 days.

The following diagram will serve to illustrate the different hosts of *Aphidius testaceipes*, *A. avenaphis*, *A. confusus*, *Aphelinus mali*, *A. nigritus*, and *A. semiflavus*, which we have shown to attack *Toxoptera graminum.* This will give some idea of the numerous sources from which an army of parasites may be recruited to oppose any serious invasion of Toxoptera.

| | | | |
|---|---|---|---|
| *Toxoptera graminum* | *Aphidius* | *avenaphis* | *Macrosiphum granaria* Buck. |
| | | *confusus* | *Macrosiphum erigeronensis* Thos. |
| | | *testaceipes* | *Aphis avenæ* Fab. |
| | | | *Aphis gossypii* Glov. *Aphis* sp. |
| | | | *Aphis maidis* Fitch. |
| | | | *Aphis maidi-radicis* Forbes. |
| | | | *Aphis medicaginis* Koch. |
| | | | *Aphis œnotheræ* Oestl. |
| | | | *Aphis rumicis* Linn. |
| | | | *Aphis setariæ* Thos. |
| | | | *Macrosiphum viticola* Thos. |
| | | | *Macrosiphum granaria* Buckt. |
| | | | *Melanoxantherium* sp. |
| | | | *Macrosiphum* sp. on black gum. |
| | | | *Myzus ribis* Linn. on currant. |
| | | | *Myzus* sp. on *Hosackia glabra*. |
| | | | *Macrosiphum* sp. on Abutilon. |
| | | | *Macrosiphum cucurbitæ* Thos. |
| | | | Aphidid on *Ampelopsis* sp. |
| | | | Aphidid on *Baccharis viminalis*. |
| | | | Aphidid on *Capsella bursa-pastoris*. |
| | | | Aphidid on *Eragrostis* sp. |
| | | | Aphidid on *Kochia* sp. |
| | | | Aphidid on locust. |
| | | | Aphidid on peach. |
| | | | Aphidid on pigweed (?). |
| | | | Aphidid on plum. |
| | *Aphelinus* | *mali* | *Aphis brassicæ* Linn. |
| | | | *Aphis monardæ* Oestl. |
| | | | *Aphis sacchari* (?) Zehntn. |
| | | | *Aphis setariæ* Thos. |
| | | | *Colopha eragrostidis* Middl. |
| | | | *Myzus mahaleb* Boyer. |
| | | | *Pemphigus fraxinifolii* Riley. |
| | | | *Macrosiphum rosæ* Linn. |
| | | | *Schizoneura americana* Riley. |
| | | | *Schizoneura lanigera* Haussm. |
| | | | *Tetraneura colophoidea* (?). |
| | | *nigritus* | *Aphis setariæ* Thos. |
| | | *semiflavus* | *Aphis maidis* Fitch. |
| | | | *Aphis gossypii* (?) Glover. |
| | | | *Chaitophorus viminalis* Mon. |
| | | | *Myzus persicæ* Sulz. |

## SECONDARY PARASITES.

### Megorismus sp.

Species of the genus Megorismus, it appears, have been previously considered as primary parasites. Mr. Parks, however, has conducted some experiments with a species (fig. 34) at Wellington, Kans., and his results clearly indicate that in this case it is a secondary parasite. In no instance could he rear it from aphidids

that had not previously been parasitized; he experienced no difficulty, however, in rearing it when the adults were placed in cages with aphidids that were brown, having been killed by some species of Aphidius. It may be that under certain conditions *Megorismus* sp. is also a primary parasite. Mr. Parks finds that it takes about 30 days in developing from egg to adult in a temperature of about 70° F. indoors.

It has been reared in conjunction with *Aphidius* sp. from *Toxoptera graminum* and *Chaitophorus* sp. at Wellington, Kans., by Messrs. Kelly and Urbahns; from *T. graminum* and *Aphis brassicæ* in the same locality by Mr. Parks. Mr. Parks also reared it from *Macrosiphum pisi* at Washington, D. C. Mr. C. N. Ainslie reared it from *Hyalopterus dactylidis* in the same locality, and the junior author reared it from *Myzus persicæ* at Lafayette, Ind.

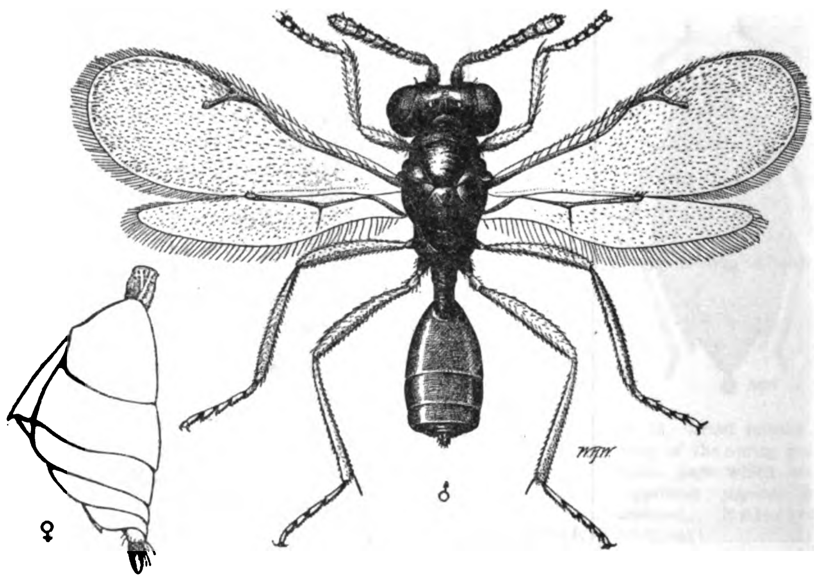



FIG. 34.—*Megorismus* sp., a secondary parasite of the spring grain-aphis: Male, greatly enlarged; female abdomen, more enlarged, at right. (Original.)

**Aphidencyrtus aphidiphagus Ashm.**

The species *Aphidencyrtus aphidiphagus* Ashm. (fig. 35) has also been considered a primary parasite, and while we have no direct evidence to disprove this we very strongly suspect that it is in this case a secondary parasite. Like Megorismus, which, we have shown, is sometimes, at least, a secondary parasite, we have reared it only in conjunction with known primary parasites. Mr. G. G. Ainslie could rear it only in connection with *Aphelinus* sp. from *T. graminum* at Clemson, S. C., and Mr. C. N. Ainslie reared it from *Aphis*

*brassicæ* at Mesilla Park, N. Mex., in conjunction with *Aphidius* sp. Nothing definite is known of its life history.

**Pachyneuron sp.**

A species of Pachyneuron (fig. 36) has been repeatedly reared from *Toxoptera graminum* and it appears to be generally accepted as a

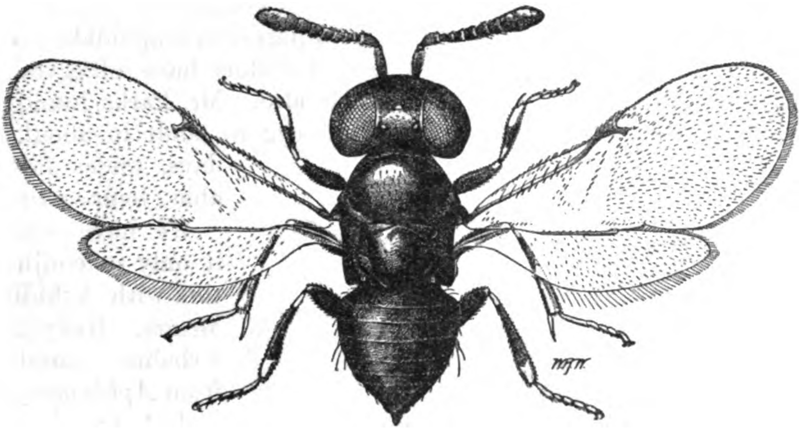


FIG. 35.—*Aphidencyrtus aphidiphagus*, a secondary parasite of the spring grain-aphis. Greatly enlarged. (Original.)

secondary parasite. Mr. Kelly has observed it ovipositing in brown parasitized *Macrosiphum viticola*. Mr. G. G. Ainslie reared it in conjunction with *Aphelinus* sp. from Toxoptera and with *Aphidius* sp. from

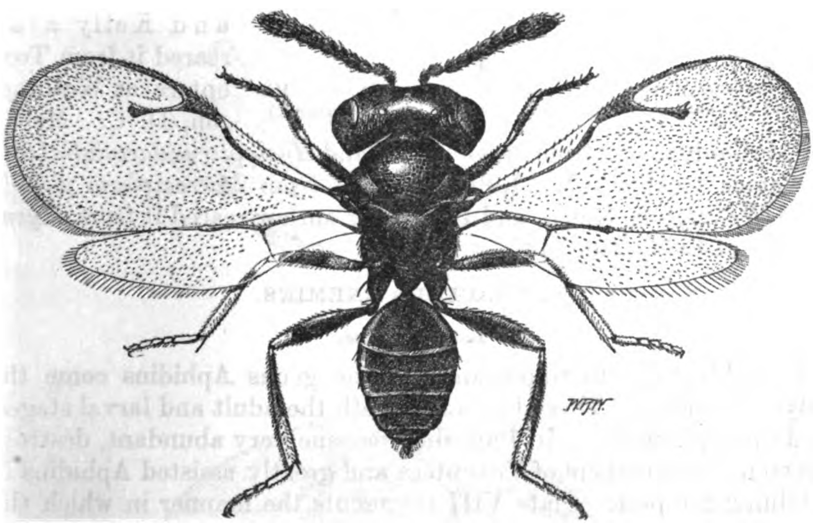


FIG. 36.—*Pachyneuron* sp., a secondary parasite of the spring grain-aphis. Greatly enlarged. (Original.)

*Aphis maidis* from Clemson, S. C., and from Toxoptera at St. Anthony Park, Minn. Mr. C. N. Ainslie reared it in connection with *Aphidius* sp. from *Aphis setariæ*, *A. gossypii*, *Macrosiphum granaria*, and *M. erigeronensis* and in connection with *Aphelinus* sp. from *Schizo-*

*neura americana*. He also reared it from *Macrosiphum viticola* and *Chaitophorus* sp. *Pachyneuron* sp. appears to be quite generally distributed but little or nothing is known of its life history.

### Allotria sp.

*Allotria* sp. (fig. 37) is recorded as a secondary parasite. Mr. Parks verified this by careful rearings at Wellington, Kans., in 1909, for he was able to rear it only from parasitized aphidids. The junior author and Messrs. Kelly and Urbahns have observed it ovipositing in parasitized dead aphidids also. Mr. Parks found in his experiments that it developed from egg to adult in about 21 days, under favorable temperatures.

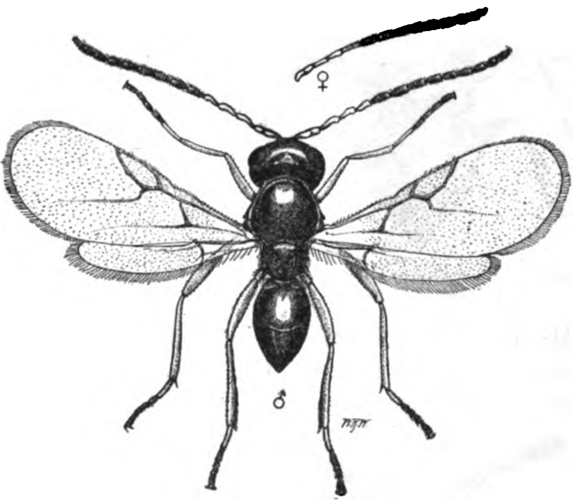



FIG. 37.—*Allotria* sp., a secondary parasite of the spring grain-aphis. Male. with female antenna at upper right. Greatly enlarged. (Original.)

We have reared it only in conjunction with Aphidius. Messrs. Kelly and Urbahns reared it from *Aphis gossypii* and *A. brassicæ* at Wellington, Kans.; Mr. Parks reared it from Toxoptera from the same locality; Messrs. Parks and Kelly also reared it from Toxoptera at Washington, D. C. Mr. C. N. Ainslie reared it from *Aphis avenæ* and *Hyalopterus dactylidis* from the same locality. Mr. Kelly reared it from *Macrosiphum viticola* from Wellington, Kans., and the junior author reared it from *Myzus persicæ* at Lafayette, Ind.

## PREDACEOUS ENEMIES.

### Lady-beetles.

Probably next in importance to the genus Aphidius come the ladybird beetles. These beetles, in both the adult and larval stages, feed upon plant-lice. In 1907 they became very abundant, destroying countless numbers of Toxoptera and greatly assisted Aphidius in subduing the pest. Plate VIII represents the manner in which the pupæ are found attached to plants in fields badly infested with Toxoptera; to the left is a 2-inch section of an old cowpea stem; to the right, two short sections of wheat stems. Oftentimes as many as 30 or more pupæ could be found within the space of a foot of a single drill row. Adults deposit eggs upon any convenient object,

Fig. 1.

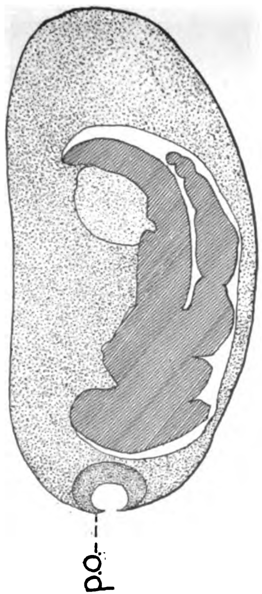



Fig. 2

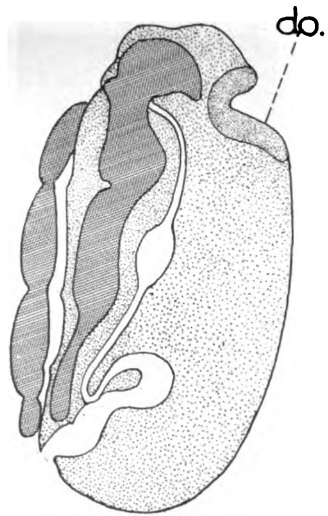



Fig. 3

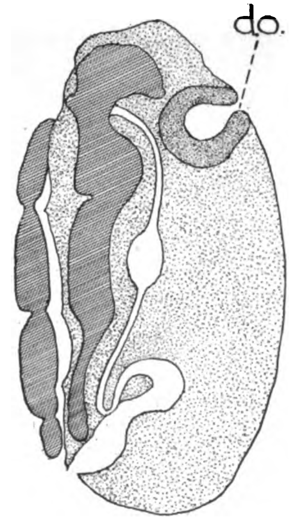
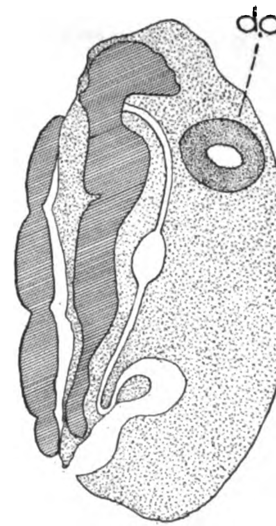
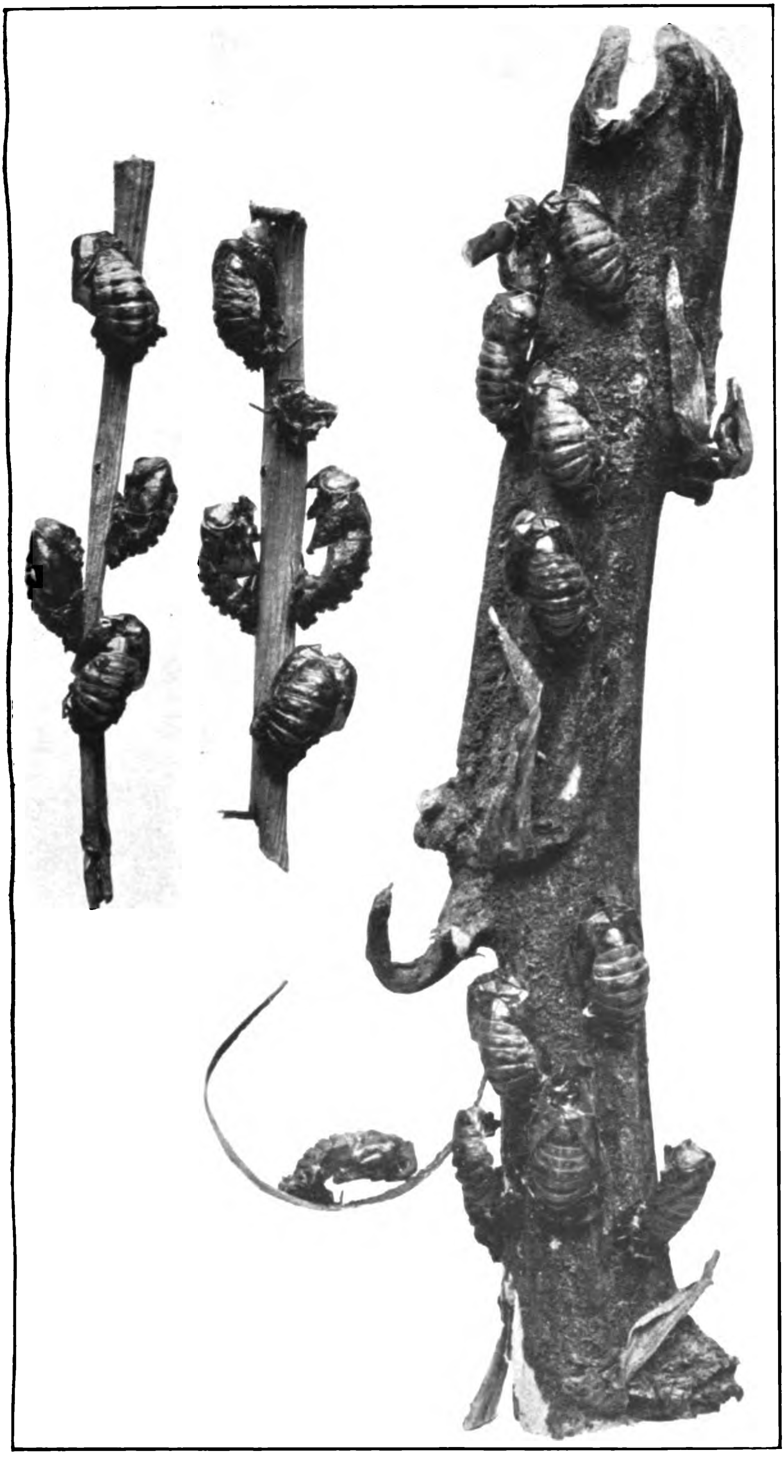



Fig. 4.




DEVELOPMENT OF THE EMBRYO IN THE EGG OF TOXOPTERA GRAMINUM.

Fig. 1.—Sagittal section (slightly oblique) showing the embryo in position to escape from the center of the egg. Magnified 83 diameters. Fig. 2.—Sagittal section (slighty oblique) showing the embryo at the surface of the egg. Dorsal organ now formed. Magnified 83 diameters. Fig. 3.—Sagittal section (slightly oblique), later stage of development. Magnified 83 diameters. Fig. 4.—Sagittal section (slightly oblique): The dorsal organ is immersed within the body cavity where it has begun to disintegrate. Magnified 83 diameters. (Original.)



A LADY-BEETLE ENEMY OF THE SPRING GRAIN-APHIS.

Pupæ of *Hippodamia convergens* attached to stem of cowpea and wheat straws in a field where the spring grain-aphis had been excessively abundant. Enlarged. (Original.)

and, as soon as hatched, the larvæ seem possessed of an insatiable appetite, devouring aphidids or even eggs and larvæ of their own species if no plant-lice are at hand. Mr. Kelly has found that an

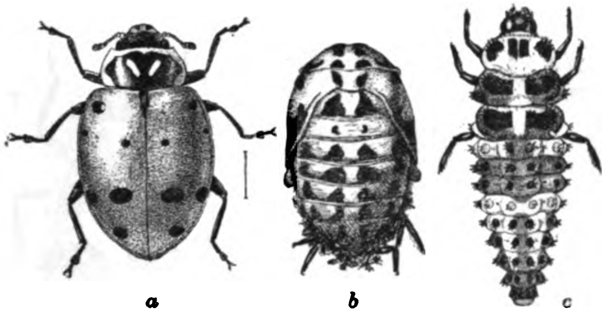



FIG. 38.—The convergent lady-beetle (*Hippodamia convergens*), an enemy of the spring grain-aphis: *a*, Adult; *b*, pupa; *c*, larva. Enlarged. (From Chittenden.)

adult ladybird (*Hippodamia convergens*) (fig. 38) will devour from 15 to 30 plant-lice in a day. Mr. S. J. Hunter, in "The Green Bug and its Enemies," page 6, states that instances have come under his observation where as many as 100 have been devoured in a single day by an adult lady-beetle. The larvæ when nearly grown are probably able even to exceed this record. In one of Mr. Kelly's experiments a single beetle deposited as many as 264 eggs, thus showing that this ladybird is very prolific. When all of these facts are considered it is easy to see that the lady-beetles are rather formidable enemies of Toxoptera.

FIG. 39.—The nine-spotted lady-beetle (*Coccinella 9-notata*), an enemy of the spring grain-aphis: Adult. Enlarged. (From Chittenden.)

*Hippodamia convergens* appeared to be by far the most abundant ladybird in the Southwest in 1907. *Coccinella 9-notata* (figs. 39, 40) and *Megilla maculata* (fig. 41) were also quite abundant. *Coccinella abdominalis* was present in less abundance. *Adalia flavomaculata* DeG. (fig. 42), with its larvæ, has been sent to the bureau as an enemy of Toxoptera in the Orange Free State, South Africa.

FIG. 40.—The nine-spotted lady-beetle (*Coccinella 9-notata*), an enemy of the spring grain-aphis: Larva. Enlarged. (From Chittenden.)

### Syrphid Flies.

All through the Southwest in 1907 syrphids were very abundant and were an important factor in the control of Toxoptera.

These insects are beautiful two-winged flies with prominent golden bands across the abdomen. They are always present in mild weather

in grain fields badly infested with plant-lice, and when quite numerous attract attention by a buzzing noise made while in flight. The predaceous larvæ are sluglike and of a dirty grayish or yellowish green color; this is the only stage in which they are destructive to

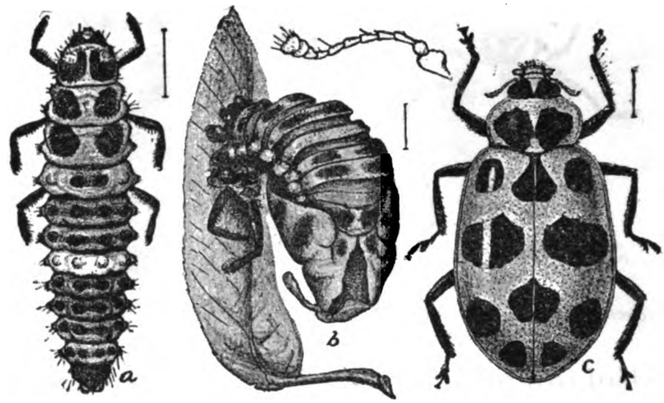



FIG. 41.—The spotted lady-beetle (*Megilla maculata*), an enemy of the spring grain-aphis: *a*, Larva; *b*, empty pupa skin; *c*, adult. Enlarged. (From Chittenden.)

plant-lice. Little is known of the life histories of these insects as very few careful rearings have been made.

*Syrphus americanus* Wied. (fig. 43) and *Eupeodes volucris* O. S. (fig. 44) were by far the most numerous syrphids in the grain fields in the Southwest in 1907. A field at Kingfisher, Okla., in April, 1907, literally swarmed with them; 20 or more could be taken with each sweep of an insect net. A curious fact with reference to their occurrence in such abundance in this field, however, was that Toxoptera was not present there in destructive abundance, while the adjoining field was suffering greatly from their attack, though, curiously enough, the syrphid flies did not appear to be so plentiful there. These two species were present, apparently, over the entire southwestern area that suffered greatly from Toxoptera attack in 1907.

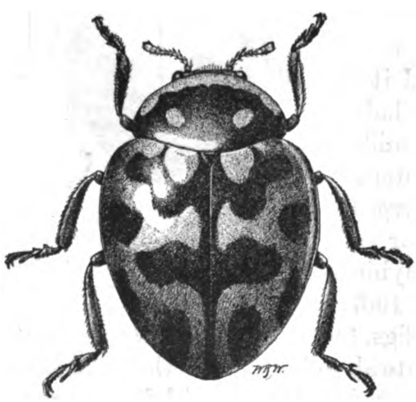


FIG. 42.—A South African lady-beetle, *Adalia flavomaculata*, which with its larva attacks the spring grain-aphis in the Orange Free State, South Africa. Enlarged. (Original.)

*Syrphus americanus* was reared also from Toxoptera material sent in by Mr. E. C. Haynsworth from Sumter, S. C. Prof. J. M. Aldrich states in his catalogue of North American Diptera that he reared *Eupeodes volucris* from *Aphis avenæ* at Moscow, Idaho. Dr. C. V. Riley states,

in a report of the Department of Agriculture,[1] that he reared *Syrphus americanus* from *Macrosiphum granaria.*

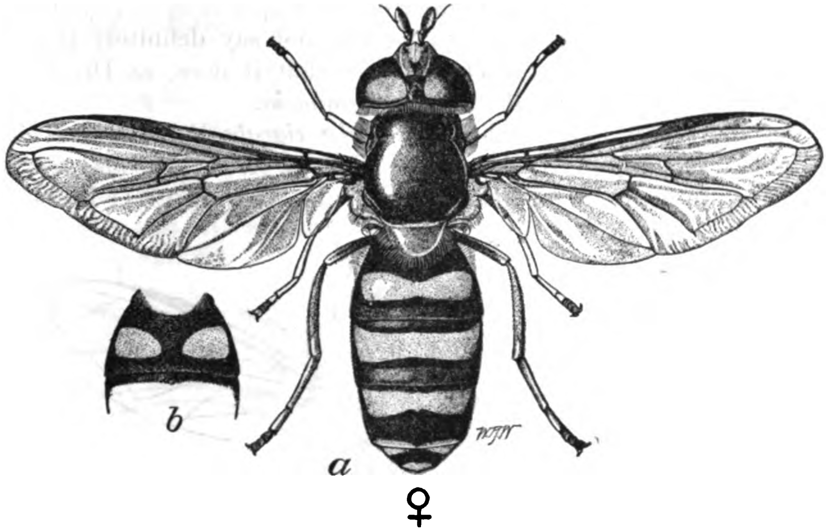



FIG. 43.—*Syrphus americanus*, whose larva destroys the spring grain-aphis: *a*, Female fly; *b*, second abdominal segment of male. Enlarged. (Original.)

*Sphærophoria cylindrica* Say (fig. 45) was collected from wheat fields at Hiawatha, Kans., in 1907, by the junior author and was also

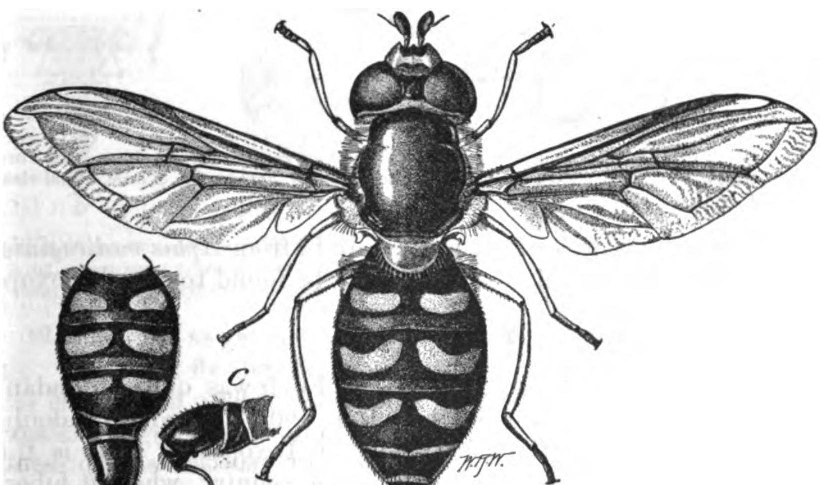



FIG. 44.—*Eupeodes volucris*, whose larvæ were the most abundant and useful in the fields where the spring grain-aphis was most abundant in the Southwest during the spring of 1907. *a*, Female fly; *b*, abdomen of male; *c*, hypopygium of male. Enlarged. (Original.)

reared from Toxoptera material sent in by Mr. Haynsworth from Sumter, S. C., the same year. Mr. G. G. Ainslie reared it from

[1] Report of the Entomologist, U. S. Dept. of Agr. for 1889, p. 351.

Toxoptera at Monetta, S. C., in 1908. Dr. Riley states that he found the larvæ feeding on *Macrosiphum granaria.*

Mr. Ainslie took quite a number of *Allograpta obliqua* Say in the Southwest in 1907, and, though we can not say definitely that it feeds upon Toxoptera, the chances are that it does, as Dr. Riley states that it feeds upon *Macrosiphum granaria.*

Mr. Kelly reared a number of *Baccha clavata* Fab. from *Aphis setariæ* at Wellington, Kans., in 1908; Mr. R. A. Vickery also reared *B. clavata* from *Aphis maidis* at Brownsville, Tex., in 1911; Mr. J. J.

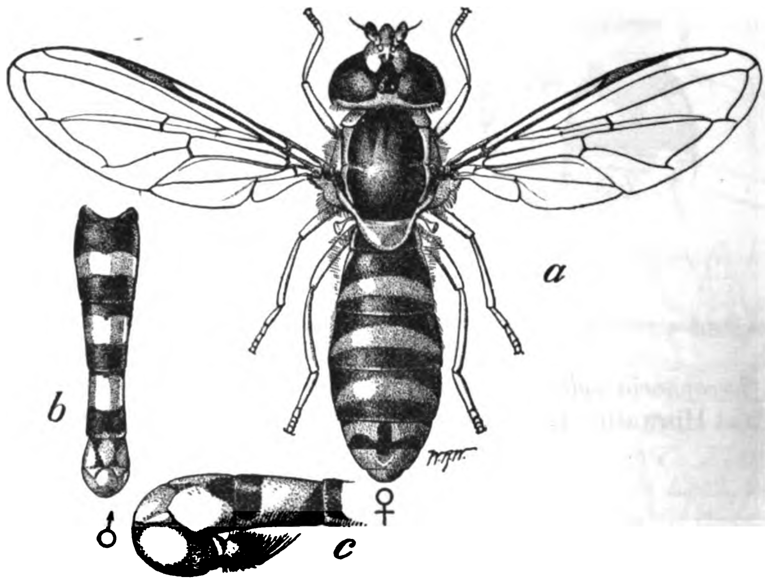



**Fig. 45.**—*Sphærophoria cylindrica*, a fly reared from larvæ attacking the spring grain-aphis in South Carolina in 1907: *a*, Female fly; *b*, dorsal view of abdomen of male; *c*, hypopygium of male, lateral view. Enlarged. (Original.)

Davis reared this species at Lafayette, Ind., from *Aphis medicaginis*, also in 1911. This species may in future be found to attack Toxoptera also.

### Lace-Wing Flies.

The lacewing fly *Chrysopa plorabunda* Fitch was quite abundant in the grain fields in the Southwest in 1907 and without doubt assisted materially in the destruction of Toxoptera. This is the most common species in this section of the country, where it hibernates in the adult stage; thus, whenever the weather becomes suitable it is ready to at once begin oviposition. An allied species is shown in figure 46.

The larvæ of these insects can move about quite freely and are provided with two long, curved mandibles (see fig. 46) upon which

plant-lice or other insects are impaled and held prisoners until they are sucked dry. They are then released and the Chrysopa larvæ hunt other victims.

**Cecidomyiidæ.**

During September of 1909, at Lafayette, Ind., a new predaceous insect enemy to Toxoptera was discovered in the larvæ of a little cecidomyiid or two-winged fly, determined tentatively for us as *Aphidoletes* sp. by Dr. E. P. Felt. It was first observed in one of the stock cages and afterwards it was found to be reproducing in the fields on *Myzus persicæ*.

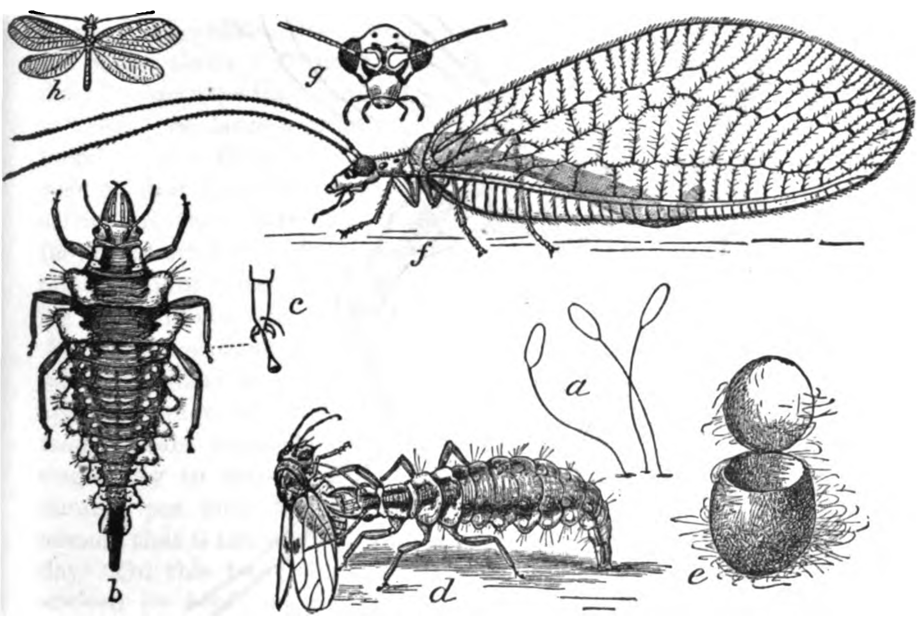



FIG. 46.—The golden-eyed lace-wing fly (*Chrysopa oculata*), an enemy of the spring grain-aphis. *a*, Eggs; *b*, full-grown larva; *c*, foot of same; *d*, larva devouring an insect; *e*, cocoon; *f*, adult insect; *g*, head of same; *h*, adult, natural size. All enlarged except *h*. (From Marlatt.)

We have not as yet carefully studied the life history of *Aphidoletes* sp. The adult fly (fig. 47) is a frail little creature, about the size of the clover-seed midge, pale cream in color, and the abdomen has a pinkish tinge, due to the pink eggs within. The eggs resemble those of the Hessian fly very closely except that they are much smaller. The larvæ (fig. 48), which are pinkish in color, descend to the ground when fully matured, and at or near the surface they spin a loose cocoon, to which particles of dirt and trash adhere. In a few days the adults issue. The time required for this little insect to complete the entire life cycle is apparently about 10 to 14 days. The species is not determinable further than the genus for the reason that only the female adults have been secured.

This little fellow goes about getting its meals in a very quiet, unobtrusive sort of way. It crawls quietly up among a number of Toxoptera and the first one it touches becomes its victim. It attaches its mouthparts to some joint of the legs, usually at the articulation of the femur and tibia, and sucks out the juices of the aphidid. With a compound miscroscope the blood can readily be seen flowing in a constant stream, through the limb of the aphidid attacked, into the larva of the cecidomyiid. Rarely is the aphid disturbed and upon close observation the skin of the aphidid will be seen to

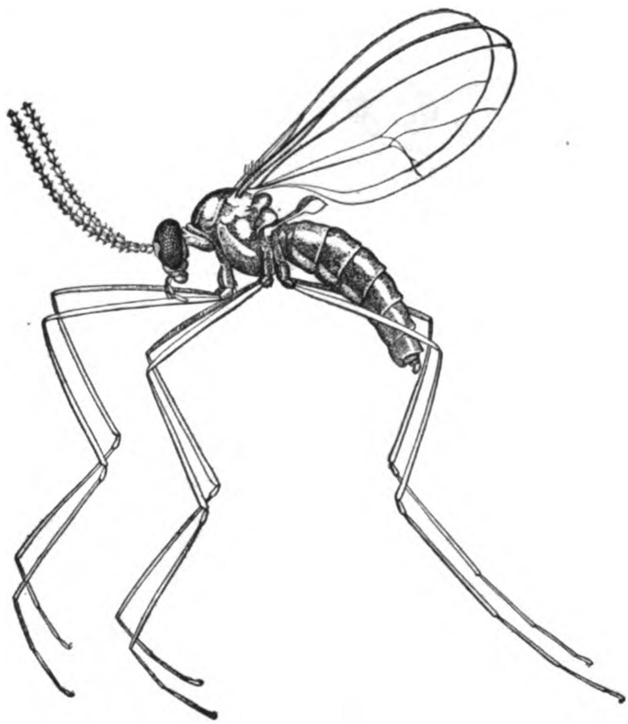


FIG. 47.—*Aphidoletes* sp., cecidomyiid fly whose larvæ feed upon the spring grain-aphis. Greatly enlarged. (Original.)

gradually shrivel up; finally nothing but the empty skin remains and the larva crawls away in search of more aphidids, frequently with the old empty aphidid skin adhering to it. The time required to consume the juices of an aphidid varies with the size of the larva and of the aphidid. A larva that is about full grown can dispatch a small aphidid in a few minutes, while from 15 to 30 minutes are required for it to empty a full-grown one. These cecidomyiid larvæ have enormous appetites and apparently keep up their work of destruction almost constantly until they become full grown.

It is not at all impossible for this insect to become a very important factor in the control of Toxoptera, as the adults are capable of flight and deposit large numbers of eggs.

**Birds.**

Birds devour immense numbers of the spring grain-aphis. Miss Margaret Morse, of Clark University, has been kind enough to conduct some experiments for us in feeding Toxoptera to quail. She has learned that they are very fond of the aphidids and estimates that about 5,000 individual Toxoptera were eaten by a single quail in one day, preference being shown for those that were unparasitized.

Mr. W. L. McAtee, of the Biological Survey of the United States Department of Agriculture, made some special studies of the aphis-eating habits of some of our birds in March-April, 1909, at Winston-Salem, N. C., at the time Toxoptera was so destructive in that vicinity. He states that in a wheat field of about 100 acres there were over 3,000 birds present daily; sometimes the number ran as high as 8,000 to 9,000. So large a number of birds would be found in the fields only during migration, and even at that time the presence of so many indicates that they were attracted to the fields by the abundant food. In so far as could be ascertained, about nine-tenths of the birds were feeding upon aphidids (including *Toxoptera graminum*, *Macrosiphum granaria*, and *Aphis avenæ*), some taking as many as 180 at a single meal. These aphidids are very small, soft-bodied insects and many meals would be required by a bird in a single day to satisfy its hunger. The average number per meal was at least 50, and we may assume that 6 times this number were taken per day. On this basis the number of aphidids destroyed by birds on the farm daily during the migration season is 90,000. Below is a partial list of the species Mr. McAtee found devouring Toxoptera at Winston-Salem. A complete list can not be given at this time, since his studies are not yet finished; many species will undoubtedly be added.

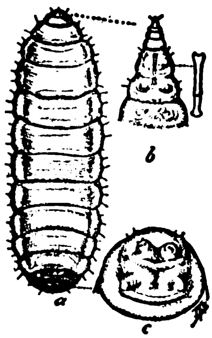



FIG. 48.—*Aphidoletes* sp., cecidomyiid larva which attacks the spring grain-aphis. *a*, Larva; *b*, anterior extremity protruded, showing breastbone; *c*, ventral view of posterior segment. *a*, Much enlarged; *b*, *c*, greatly enlarged. (Original.)

Goldfinch (*Astragalinus tristis*).
Vesper sparrow (*Poœcetes gramineus*).
Savanna sparrow (*Passerculus sandwichensis savanna*).
Chipping sparrow (*Spizella socialis*).
Song sparrow (*Melospiza melodia*).

All of these birds occur over the entire South.

## MISCELLANEOUS ENEMIES OF TOXOPTERA.

Under the head of miscellaneous enemies may be considered enemies that are of very slight economic importance; those, in other words, that have been observed occasionally attacking Toxoptera.

In 1890 the senior author, at Lafayette, Ind., found that the young of the snowy tree-cricket (*Œcanthus niveus* De G.) were very fond of Toxoptera and fed upon them freely.

Mr. A. N. Caudell, of this bureau, observed one of the soldier bugs, *Reduviolus ferus* L., attacking Toxoptera on the grounds of the Department of Agriculture at Washington in 1908. During the same year Mr. C. N. Ainslie found a larva of a species of the ladybird genus Scymnus at Mesilla Park, N. Mex., attacking Toxoptera, and he seems to think that numbers are devoured by this insect.

In 1909, at Washington, D. C., Mr. R. A. Vickery reared the braconid *Lipolexis piceus* Cress. in limited numbers from Toxoptera.

The junior author has at times found a fungous disease attacking the aphidids in his rearing cages, but we have never noted this in the fields.

### ANTS AND THEIR RELATION TO TOXOPTERA.

So far as our observations go Toxoptera is not so attractive to ants as are many other species of plant-lice. We have often found various species of ants in attendance on Toxoptera, but the relations did not appear to be mutually beneficial, the ants nearly always gaining the most by such partnerships.

At Hooker, Okla., in 1907, the junior author found ant burrows beside plants in an area badly infested with Toxoptera. In this case some burrows were found where the aphidids were slightly below ground on plants in these burrows, the ants being busy about the aphidids, stroking them with their antennæ. Mr. C. N. Ainslie many times observed ants stroking Toxoptera with their antennæ. We have found no instances, however, in which ants care for the eggs of Toxoptera in winter, and Toxoptera does not appear to excrete so much honeydew as do some other aphidids. This probably accounts for the fact that they are not so popular with the ants as are certain other aphidids.

In Texas, during 1909, Mr. T. D. Urbahns found ants busily caring for Toxoptera in his rearing cages. He also noted that the ants always attacked the parasite of Toxoptera (*Aphidius* sp.) whenever they came in contact with it, tearing the larvæ out of the old dead bodies of Toxoptera and destroying them.

## REMEDIAL AND PREVENTIVE MEASURES.

With an outbreak of this pest fully established, and the winged adults being carried by the winds and scattered over the fields, there to settle down and reproduce, the difficulties in the way of control are quite insurmountable.

### FIELD EXPERIMENTS.

The brush-drag experiments that were carried out under the direction of the junior author at Hobart, Okla. (see Plate IX, fig. 1), have not, with the trials we have given the brush drag, proved satisfactory, although Mr. Thos. J. Anderson, Government entomologist of British

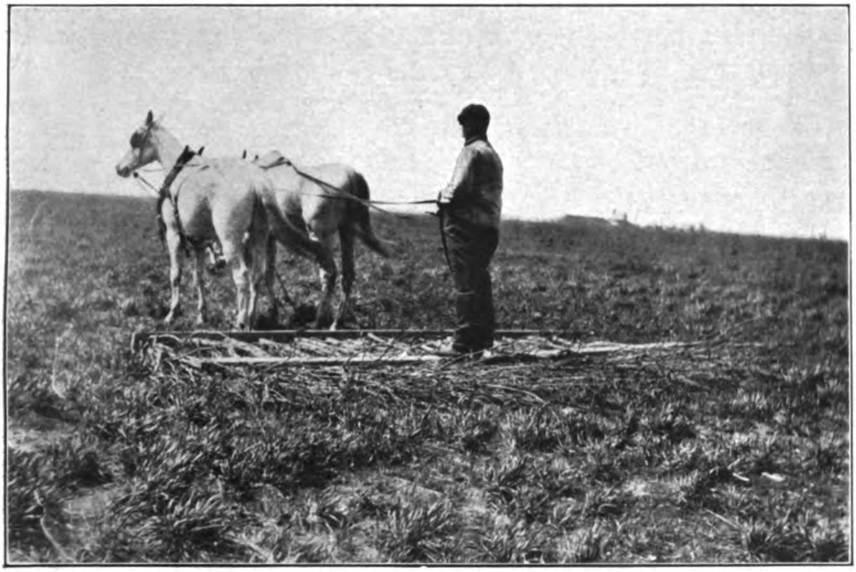


FIG. 1.—BRUSH DRAG USED BY THE JUNIOR AUTHOR IN EXPERIMENTS AND ALSO BY FARMERS IN DESTROYING THE SPRING GRAIN-APHIS IN THE FIELDS AT HOBART, OKLA. (ORIGINAL.)

FIG. 2.—ROLLER USED IN EXPERIMENTS BY JUNIOR AUTHOR AND BY FARMERS IN DESTROYING THE SPRING GRAIN-APHIS IN OKLAHOMA. (ORIGINAL.)

East Africa, states that it is with them the most effective measure at their command for destroying the "green fly" in wheat fields. With us it was used after the aphidid had fully established itself and was literally swarming over the growing grain. Earlier, at the commencement of an outbreak, the effect of its use might prove more satisfactory.

Similar experiments were carried out with a heavy roller, such as is generally used among farmers for crushing clods in fields and compacting the ground. (See Pl. IX, fig. 2). In this case the results were even less satisfactory than with the brush drag, because the roller acted only on the clods and other inequalities in the surface of the ground. Where the wheat had been drilled the effect on the Toxoptera was less decisive than where the grain had been sown broadcast. The wheat plants grow in the narrow furrows or grooves and the insects that were displaced dropped down about the plants and the passing roller struck only the ridges, leaving the insects practically untouched.

Where the invasion is not chiefly from outside the field itself, and the pest makes its first appearance in spots, management is less difficult. By plowing under these infested spots and immediately harrowing and rolling them further damage may be effectually prevented. The junior author had an opportunity to test this measure in western Oklahoma. Covering these spots with straw, where easily obtainable, and burning, is equally effective, but where this last measure was applied by farmers in Oklahoma in 1907 the fields were so completely overrun from the outside that the good effects were entirely obliterated.

As between these two methods of suppression, it must be borne in mind that while the seriously affected spots in a field are very small, a single load of straw will suffice to cover a number of them, preparatory to burning, but after these areas become enlarged it is much more practicable to plow them under.

Besides the above-mentioned methods of control, experiments were conducted with different kinds of spray materials. In all of our control methods we endeavored to place ourselves in the position of the farmer, and to use such apparatus as could be obtained locally. Accordingly the junior author, upon reaching Hobart, Okla., the first week in April, 1907, prepared to begin some spraying experiments. The only spray apparatus that could be found in the town was a knapsack pump. As stated above, since an outbreak of Toxoptera starts in small areas, where the infestation originates within the field, it was thought possible to accomplish something by spraying these areas. As the infestation at Hobart seemed to be quite general, apparently originating from migrations from farther south and east, the small pump was found to be utterly useless. From here the junior author proceeded to Kingfisher, Okla., where there were clearly defined areas of infestation, and, together with

Mr. C. N. Ainslie, began experiments with a barrel pump, loaned by a market gardener. One plat was sprayed with 5 per cent kerosene emulsion; another with 10 per cent kerosene emulsion; a third plat with ordinary hard soap, 1 pound to 4 gallons of water; a fourth plat with whale-oil soap, 1 pound to 6 gallons of water. The spraying was done carefully, so as to reach every aphis possible. Upon examination the next day it was found that the 10 per cent emulsion and the hard soap had injured the plants. Not more than 50 per cent of the plant-lice were killed in any of the experiments. On the 15th of April the sprayings were repeated with similar results. All of the aphidids could not be reached, no matter how thoroughly the spraying was done. It was quite evident that unless the ground was almost soaked there would be little or no relief. These sprayings cost at the rate of about $4 per acre.

During the latter part of July it was found that Toxoptera was very abundant on the lawns of the Department of Agriculture at Washington, D. C. This outbreak became known to Mr. E. M. Byrnes, Superintendent of Experimental Gardens and Grounds, who at once had the entire infested block sprayed with a solution of one-half gill of blackleaf tobacco extract to each gallon of weak soapsuds. The application was, however, ineffective. Four days later a strip through this plat was thoroughly saturated with a strong solution of barnyard manure, made by soaking the manure in water. While there was no evidence that this killed any of the "green bugs," after nine days the pest was visibly less on this area than where the application of manure solution was not made.

A series of experiments was then undertaken under the senior author's direction by Mr. E. O. G. Kelly, as follows:

Tobacco dust was applied at rates of one-fourth, one-half, and 1 pound to each 100 square feet, but after over a week had elapsed from the date of application no effect was to be observed and no dead insects were found.

Kerosene emulsion was applied at 8 and 10 per cent strengths, and at the end of nine days no "green bugs" were to be found on the areas so treated. Also there was no perceivable injury to the grass.

Whale-oil soap solutions, varying in strength from one-fourth of a pound to 2 pounds of soap to each 5 gallons of water, were applied to similar areas. In this case the stronger solution injured the grass slightly, but not permanently; in the case of the lesser strengths there was no injury to the grass whatever. The effect on the "green bug" was the same in every case. They were not only literally exterminated over the areas treated, but the applications seemed to protect from a reinfestation, in case of even the weakest solution. An examination five days after the application was made revealed the "green bugs" in myriads and breeding freely on the untreated space, while only 8 inches away and on the treated area living bugs were

scarcely to be found, although the dead bugs were to be observed almost as abundantly as were the living on the space untreated. It must be remembered, however, that these experiments were carried out in grass kept closely cropped by frequent use of the lawn mower, and such areas can be sprayed much more effectively than a wheat field, where the ground would have to be literally soaked in order to reach all of the aphidids.

In the light of these experiments field spraying seems an impractical measure, even when small areas are involved. Burning or plowing would probably be more effective and the recommendations would probably be more readily complied with, as the average farmer does not usually have spray pumps of any description.

Lime and sulphur was dusted on the plants in badly infested areas with practically no benefits.

### CULTURAL METHODS.

Examination of a large number of fields infested by Toxoptera, extending over a wide range of country, resulted in securing a considerable mass of information that may be included under the head of cultural methods.

The senior author visited Sumter, S. C., April 17, 1907, driving over much of the country in that vicinity. All fields of fall-sown oats, the only grain grown, were infested, there being no perceivable difference in severity of attack between fields following cotton, those following oats, and those on new ground, thus showing that the pest had swept over the country, diffusing itself generally.

At Winston-Salem, N. C., April 19–20, where both wheat and fall oats were grown, the ravages of the pest were much more serious, and fall-sown oats were completely ruined. A part of one field that had been in oats the previous year had, that fall, thrown up a heavy growth of volunteer grain, while the remaining portion was free of this growth. Wheat was drilled directly across both these areas on November 15, 1906, the whole field having first been prepared by disking, leaving much of this volunteer grain undisturbed. April 20, 1907, when examined by the senior author, the wheat on the part that had been overgrown with volunteer oats the previous fall was totally ruined, while on the clean part the damage was about 50 per cent. In wheat fields generally there was a marked difference in severity of attack as between those seeded before and those sown after about November 1, 1906, the later-sown suffering little while that sown earlier, on ground where there was much volunteer wheat or oats, was seriously damaged. This indicated that the trouble had been aggravated by the volunteer growth at the time of wheat seeding the previous autumn. It was very significant that in late-sown fields on clean ground the injury was comparatively small.

In Oklahoma it was observed by both the junior author and Mr. C. N. Ainslie that late-sown and pastured fields were destroyed much

more quickly and completely than earlier sown, unpastured fields. But it must be remembered that here the almost universal destruction was caused principally by Toxoptera drifting in from outside sources.

One feature of attack by Toxoptera has been especially noticeable throughout most portions of the country seriously ravaged by the pest, particularly where only wingless viviparous females have been found. In such fields the destruction was confined to circular areas which constantly increased in size as the season advanced, so long as meteorological conditions favorable to the increase of the pest prevailed; unless, in the meantime, the entire field had become overrun from the swarms drifting in from without. The occurrence of these spots (see Plate I, fig. 2) in the fields, while general, is not universal. For instance, the senior author did not observe them in the fields of fall-sown oats in South Carolina, in April, 1907, but he did find them about Winston-Salem, N. C., a day or two later. At Summers, Ark., Mr. C. N. Ainslie, observed a field of wheat, March 18, 1907, where a rectangular strip at one end had been totally killed out by Toxoptera, and learned from the owner that this area exactly corresponded with that of a small patch of oats which the previous year had failed to produce more than a very poor crop and had been plowed under without cutting. In preparing the ground for wheat in the fall of 1906, a volunteer growth of oats was reported to have sprung up on this area after plowing. Again the same observer, a little later in the season, found that the regularity of the occurrence of these spots in rows across a field, in northern Oklahoma, exactly corresponded to the location in this same field the previous summer of oat shocks, which had been allowed to stand out through a period of wet weather; the volunteer grain having sprung up there later in the season and remained growing amongst the young wheat in the fall. In Texas the relation of this volunteer growth in the fields, in autumn and early winter, to the abundance of Toxoptera does not appear to differ materially from what is known to occur elsewhere. When the secretary of the Texas Grain Dealers' Association first appealed to the Government for aid in investigating the pest, particular attention was directed to the possibility that methods might be devised for its control by spraying or otherwise treating the spots in grain fields, for the purpose of checking its ravages before these infested spots had increased in size and before the pest had spread from them over the entire field.

Thus it will be seen that primarily infestation is first invited by the volunteer growth starting up in cultivated fields in autumn. If such fields are sown to wheat or oats in the fall, the pest spreads from this earlier growth to the younger and more tender grain. This will of itself suggest several entirely practical cultural methods likely to restrict and prevent the development of the pest in the fields in autumn.

Crop rotation could scarcely fail of giving beneficial results. The destruction of all volunteer grain springing up in fields from which grain has been removed at thrashing gives promise of the greatest relief. Indeed, if careful attention were given to all fields in autumn, and all of this volunteer growth were destroyed before any grain whatever was sown, it is doubtful if such serious ravages as have occurred in the past could be repeated. This can all be accomplished by close pasturing and careful late plowing, followed as soon as possible by seeding.

At Hooker, Okla., the junior author found affected spots both on land that had been devoted to oats the previous year and on land that had previously grown cowpeas. This, as well as some other observations made by other parties, indicates that some of the grasses will have the same effect in inviting attack as volunteer grain growing up in the fields in the fall.

It is therefore most urgently recommended, and especially for the South, that all of this volunteer growth of whatever nature be completely killed out in the fields before seeding the following crop. Not only will this mode of procedure benefit especially the southern grain grower, but in the light of our present knowledge of the pest, it will serve as a protection to the spring oats crop over a large area of country where it is doubtful if serious ravages would occur at all were there not myriads of the pest continually developing to the South and drifting northward in spring with the advance of the season.

Following along the same line, attention should be directed to the probability that late seeding may prove a preventive of attack, for the reason that the pest will obviously gain less of a foothold in a late-sown field than it will where there has been an early growth of young grain plants. In other words, there is a likelihood that the pest may break out in spots, as has been several times previously noted, and to this extent late seeding is an advantage. However, this would be a serious disadvantage if the fields should afterward be overrun by hordes of migratory winged viviparous females in spring, for in this case the earlier sown and therefore the older and less succulent growth would suffer least from their attack. This is shown by the fact that late-sown and winter-pastured fields in Oklahoma suffered most in 1907. It must also be noted that at Winston-Salem, N. C., in April 1, 1907, wheat that had been sown about or a little prior to November 15, on ground free from young growth of volunteer grain, or the grasses, was practically uninfested even though located in the immediate vicinity of other badly infested fields sown earlier on ground more or less foul with young growth. All of this indicates pretty clearly that if all volunteer growth were eliminated in the fall, and the grain sown late, the pest would not become destructive. Of course the amount of benefit secured will depend upon the uniformity with which this method is carried into effect in any locality.

Over the northern part of the country where the insect passes the winter largely or wholly in the egg state, another measure can be applied to great advantage. The junior author has found that blue grass (Poa) is not only a summer food plant, but that it is very largely upon this grass that the eggs are deposited in the fall, and from which the offspring of the stem mothers make their way to the grain fields in spring. He has observed cases where the portion of a grain field bordered by bluegrass was the most seriously affected part of the entire field. If, then, roadsides, fence corners, and other waste lands were closely grazed in fall, winter, or early spring, these eggs would be largely destroyed and the food supply of the stem mother and her progeny cut off. This can always best be done during mild winters on account of a lack of snow. Where close pasturing is not practicable, burning over during the same season will have a similar if not an even more drastic effect.

## ARTIFICIAL INTRODUCTION OF PARASITES.

As *Aphidius testaceipes* destroyed such hordes of Toxoptera in apparently very short periods of time, after they had once become established, we thought it possible materially to aid in this destruction by introducing the parasites artifically into localities where they were apparently absent. As Mr. C. N. Ainslie was unable to find any evidence of parasitization in the fields about Wellington, Kans., on April 1, 1907, it was decided to begin operations there. Accordingly, on April 9, over a bushel of wheat leaves that were almost covered with parasitized Toxoptera were collected at Kingfisher, Okla. Mr. Ainslie took charge of this material, and on April 10, made a careful survey of the fields about Wellington, Kans., to determine the situation relative to Toxoptera infestation, and on the morning of April 11 he scattered a portion of this material in one of the most badly infested fields that could be found in that vicinity, the remainder being left sheltered by the box lids. At this time he could find parasitized Toxoptera already in the fields, both the dead leathery bodies and those showing the characteristic yellow color. The parasites included in this introduction were roughly estimated at 2,500,000; this number, however, was probably not a "drop in the bucket" to those already in the field. If there were only one or two parasitized Toxoptera to a leaf, when a whole field is considered 2,500,000 would seem to be a very small number. So far as published records show this was the first artificial introduction of parasites into Kansas.

April 12 another lot of parasitized material, sent Mr. Ainslie by the junior author from Kingfisher, which was fully as large as the previous consignment, was introduced into another field 2 miles from the first. All of this material, originally intended for one field, was reported as one experiment by the junior author and appeared as one experiment in Circular 93, since Mr. Ainslie's notes were not on file in the office at the time. We find, however, that Mr. Ainslie,

on his own initiative, conducted two separate experiments, thus rendering the results twice as valuable.

April 18 a minor introduction of parasites was made at McPherson, Kans., and on April 21 there was another similar one at Sterling, Kans. Parasitized "green bugs" were observed present at each place on these dates.

Mr. Ainslie remained in the vicinity of Wellington, and more briefly at McPherson and Sterling, for the purpose of making accurate observations on the effect of these introductions.

Two weeks later, on visiting the two fields at Wellington, where the first introduction had been made, Mr. Ainslie found that on account of the cold weather the effect upon the parasites was almost the same as though they had been kept in cold storage. Some of those sheltered by the box lids had issued, but had apparently not ventured far from their shelter and were found in a semitorpid condition capable of little movement. The percentage of parasitism from Aphidius appeared to be the same in all other fields in this locality, irrespective of these introductions, except close about the box lids, where they seemed a little more numerous, the conditions of parasitization generally being about the same as had existed two weeks previous. The Toxoptera, however, had greatly increased in numbers, and the fields were now plainly showing the effects of their work.

Subsequent examinations of fields at Wellington showed that after the weather warmed up in May the parasites speedily overcame the Toxoptera and that the fields where these artificial introductions were made had suffered as much as any fields in the neighborhood from attack by the "green bug." All of this seems to indicate that no noticeable good resulted from these introductions, which, in the light of our present knowledge, is not at all surprising. The minor experiment at McPherson was also reported upon to us by Mr. W. Knaus, and his report was in accord with our own observations.

On May 17 an artificial introduction of parasites was begun at Manhattan, Kans.[1] While this experiment bore out our former observations, the results obtained here should not bear as much weight as the earlier introductions, since the Toxoptera was already nearly overcome when the introduction was begun.

When one stops to consider the numerous and varied hosts of *Aphidius testaceipes*, its manner of hibernation, its wide distribution, and the higher temperature required for its development over and above that needed by its host; also the fact that it may readily be transported along with its host as adults, or within the body of the latter, one can readily see the futility of attempting materially to increase its numbers or efficiency by artificial introduction into grain fields.

[1] Cir. 93, Bur. Ent. U. S. Dept. Agr., pp. 10-12, Aug. 22, 1907; Cir. 93, revised, Bur. Ent., U. S. Dept. Agr., pp. 12-13, June 23, 1909.

## LITERATURE CONSULTED.


ALDRICH, J. M.—Catalogue of North American Diptera.
ALDRICH, J. M.—Cultivator and Country Gentleman, vol. 47. p. 498, June, 1882.
ASHMEAD, WM. H.—Proc. U. S. Nat. Mus., vol. 11, 1888.
BIRO, LAJOS.—Rovartani Lapok, vol. 2, p. 127, 1885.
BUCKTON, G. B.—British Aphides, vol. 1, p. 80.
BUCKTON, G. B.—British Aphides, vol. 3, pp. 135–136.
DEL GUERCIO, GIAC.—Nuove relazioni ai lavori della R. Stazione di Entom. Agraria di Firenze, ser. 1, no. 2, pp. 144–145, 1900.
HEGNER, R. W.—Biol. Bul., vol. 16, no. 1, pp. 19–26, 1908.
HEGNER, R. W.—Journ. Morph., vol. 20, pp. 231–296, 1909.
HORVATH, G.—Rovartani Lapok, vol. 1, p. 143, 1884.
HORVATH, G.—Fauna Regina Hungarie, vol. 3 (Insecta Hemiptera), p. 60, 1897.
HOWARD, L. O.—Ent. News, vol. 19, no. 8, pp. 365–367, 1908.
HUNTER, S. J.—The green bug and its enemies, Bul. Univ. Kans., vol. 9, no. 2, 1909.
HUXLEY, T. H.—Trans. Linn. Soc., vol. 22, pt. 3, p. 215, 1858.
KELLY, E. O. G.—Proc. Ent. Soc. Wash., vol. 10, nos. 3–4, pp. 163–164, 1908.
KELLY, E. O. G.—Proc. Ent. Soc. Wash., vol. 11, pp. 64–66, 1909.
LECAILLON, A.—Contribution à l'étude des premiers phénomènes du développement embryonnaire chez les insectes, particulièrment chez les Coléoptères. Archives D'Anatomie Microscopique, tome 1, 1897.
LECAILLON, A.—Recherches sur le développement embryonnaire de quelques Chrysomélides. Archives D'Anatomie Microscopique, tome 2, 1898.
MACCHIATI, LUIGI.—Bol. Soc. Ent. Ital., vol. 14, p. 246, 1882.
MANNS, THOS. F.—Bul. 210, Ohio Agr. Exp. Sta., 1909.
MAXWELL-LEFROY, H.—Agricultural Journal of India, vol. 3, pt. 3, pp. 243–244, 1908.
MAZZANTI, DR. DOM LUIGI.—Nuov. Ann. Sci. Nat. Bologna, ser. 3, vol. 6, pp. 342–352, 1852.
PASSERINI, GIOVANNI.—Gli afidi (pamphlet), p. 25, 1860.
PERGANDE, THEO.—Bul. 38, Div. Ent., U. S. Dept. Agr., pp. 7–19, 1902.
PHILLIPS, W. J.—Proc. Ent. Soc. Wash., vol. 10, nos. 1–2, pp. 11–13, 1908.
RILEY, C. V.—Rept. U. S. Dept. Agr. for 1889.
RILEY, C. V., and HOWARD, L. O.—Insect Life, vol. 3, pp. 73–76, 1890.
RONDANI, CAMILLO.—Nuov. Ann. Sci. Nat. Bologna, ser. 2, vols. 8, 9, 1847.
RONDANI, CAMILLO.—Nuov. Ann. Sci. Nat. Bologna, ser. 3, vol. 6 (2), pp. 9–12, 1852.
SAJO, KARL.—Zeitschr. f. Pflanzenkrankheiten, vol. 4, p. 4, 1894.
SAJO, KARL.—Prometheus, vol. 1, 1889 (1890).
SCHOUTEDEN, H.—Mem. Soc. Ent. Belg., vol. 12, p. 231, 1906.
SETTERMAN, G. W.—Colman's Rural World, vol. 53, p. 193, 1890.
STAHL, J. M.—Country Gentleman, vol. 55, p. 639, 1890.
TANNREUTHER, G. W.—History of the germ cells and early embryology of certain aphids. Zoologische Jahrbucher, Band 24, Heft 4, 1907.
WASHBURN, F. L.—Can. Ent., vol. 40, pp. 53–54, February, 1908.
WASHBURN, F. L.—Special Report of the State Entomologist of Minnesota, March 1, 1908.
WASHBURN, F. L.—Weather Crop Bul. Mo. State Bd. Agr., 1890.
WEBSTER, F. M.—Insect Life, vol. 4, pp. 245–248, 1892.
WEBSTER, F. M.—Cir. 93, Bur. Ent., U. S. Dept. Agr., 1907.
WEBSTER, F. M.—Cir. 93, revised, Bur. Ent., U. S. Dept. Agr., 1909.
WEBSTER, F. M.—Proc. Ent. Soc. Wash., vol. 9, pp. 110–114, 1907.
WEBSTER, F. M.—Ann. Ent. Soc. Amer., vol. 2, no. 2, pp. 67–87, 1909.
WEED, C. M.—Ohio Farmer, vol. 78, no. 3, p. 33, July 19, 1890.
WHITE, GILBERT.—Natural history and antiquities of Selbourne, pp. 365–366, 1836.
WILL, LUDWIG.—Entwicklungsgeschichte der viviparen Aphiden. Zool. Jahrb. Abth. f. Anat., Bd. 3, pp. 201–286, 1888.
WITLACZIL, EM.—Entwicklungsgeschichte der Aphiden. Zeitschr. f. Wiss. Zool., Bd. 40, 1884.

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O

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 111.
L. O. HOWARD, Entomologist and Chief of Bureau.

# THE HOP APHIS IN THE PACIFIC REGION.

BY

WILLIAM B. PARKER, M. S.,
*Entomological Assistant.*

ISSUED MAY 6, 1913.

WASHINGTON:
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1913.

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Marion T. Van Horn, Pauline M. Johnson, Anita M. Ballinger, Cecilia Sisco, *preparators.*

# LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
*Washington, D. C., December 21, 1912.*

Sir: I have the honor to transmit herewith the manuscript of a paper entitled "The hop aphis in the Pacific region," prepared with admirable thoroughness by Mr. William B. Parker, Entomological Assistant. The topic is one which has engaged Mr. Parker's attention for two seasons, 1911 and 1912. The work covers investigation in the States of Washington, Oregon, and California. The principal work was conducted in California, but the author has had considerable experience with hop insects, including the hop aphis, in British Columbia. The principal insect pests of the hop have not, until recent years, had adequate treatment in publications on economic entomology, and this paper should therefore prove of great value to hop growers.

I recommend its publication as Bulletin No. 111 of this bureau.

Respectfully,

L. O. Howard,
*Entomologist and Chief of Bureau.*

Hon. James Wilson,
*Secretary of Agriculture.*

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# THE HOP APHIS IN THE PACIFIC REGION.

(*Phorodon humuli* Schrank.)

## INTRODUCTION.

The hop aphis (*Phorodon humuli* Schrank) was known as a pest in the hop gardens of England and of Continental Europe long before hop growing became an industry in America. In the United States this aphis first appeared in New York in 1863, in Michigan in 1866, and in Wisconsin in 1867, and in these States it seriously injured that crop during the early eighties. It soon reached the Pacific Coast, where it first appeared in 1890, and it is now troublesome in most of the hop-growing sections of British Columbia, Washington, Oregon, and California.

The investigation upon which this paper is based began during the spring of 1911 and was continued through two seasons, being completed in the fall of 1912. Experiments were conducted and practical control work was carried on at Sacramento and Santa Rosa, Cal., and at Independence, Oreg. The recorded efficiency of the various insecticides tested is based upon actual counts of living aphides, made before and after spraying. The data upon the cost of control work and methods employed in field operations are based upon the work at Santa Rosa, Cal., and Independence, Oreg., where the prime object of this investigation was carried out, i. e., the economical control of the aphis of the hop.

Acknowledgments are due to Dr. F. H. Chittenden, in charge of Truck Crop and Stored Product Insect Investigations; to Mr. J. Williamson, of Santa Rosa, Cal., who generously assisted me in some of the experimental work; to Mr. Theo. Eder, superintendent of the E. Clemens Horst Co., who furnished me with a field laboratory and a temporary assistant during the summer; to Mr. R. S. Raven, who ably assisted me in the life-history and experimental work, and to Mr. H. N. Ord, who collected much of the data upon methods and cost of control and who carried out the field work in Oregon.

## ECONOMIC IMPORTANCE.

The hop aphis has probably been present on the Pacific coast since the time hops have been grown there on a large scale. The greatest injuries from this pest occur in Oregon, Washington, and British Columbia, but serious losses are occasionally sustained in California.

In 1911 the hops at Santa Rosa, Cal., were severely attacked by this aphis. In fact, if the hop crop of the world had not been small and the demand for hops consequently very great, many of the growers in this section would have been unable to dispose of their crops. During the same season the financial loss due to injury by this aphis to the crops on two large yards in British Columbia was estimated at $80,000.

In 1912 the loss due to this insect was particularly severe in Oregon. One company which handles about 20,000 bales estimated that 50 per cent of their hops were badly damaged and would sell for 15 cents per pound, while 30 per cent was slightly damaged and would sell between 15 and 18 cents per pound. The remaining 20 per cent was not injured and would sell for the prevailing price of 20 cents. At this rate the loss would aggregate $124,000. The crop on a yard of 110 acres was so severely injured that 20 acres were not worth picking. The loss in this yard was $12,000.

The damage in these cases was unusually severe, but this pest if not controlled is, under favorable conditions, capable of causing such injury to both the hopvines and the hop cones as to entail a total loss.

## LIFE HISTORY.

### HIBERNATION.

The winter egg is deposited by the oviparous female upon the plum, prune, and hop in the Pacific Coast States and upon the sloe, plum, bullace,[1] and probably the hop in England and Continental Europe.

The first generation and the winged migrants were observed upon French prune at Santa Rosa and Perkins, Cal., during May and June in 1911 and 1912. The migrants which were observed May 29, 1912, were upon the ordinary though tender foliage, but those observed later in the season were found only upon some very succulent, suckerlike growths. No hop aphides were found upon the surrounding older and tougher leaves. This observation was made both in Santa Rosa and Perkins, and it was found that by selecting such growths aphides could almost invariably be found.

### APHIDES ON HOP ROOTS.

Prof. W. T. Clarke, of the California Experiment Station, stated that while studying this insect at Watsonville, Cal., during the last of January or first of February, 1904, some hop roots were brought to him on which were many living hop aphides. He stated that there is no doubt about the identification of this insect. The writer

[1] Journ. Board Agr. Great Britain, vol. 19, No. 4, p. 297, 1912.

was unable to find this condition, but the foregoing data show the possibility of another method of hibernation.

Many examinations of hop roots were made during this investigation, but no eggs of the hop aphis were discovered on or near them. The following data, however, lead the writer to believe that the aphides very frequently hibernate on or around the hop roots.

Wingless viviparous hop aphides were observed depositing young upon the lower leaves of a hopvine at Santa Rosa, Cal., March 16, 1912. This vine was half a mile from any prune tree. Many small wingless aphides were observed on the lower leaves of hopvines at

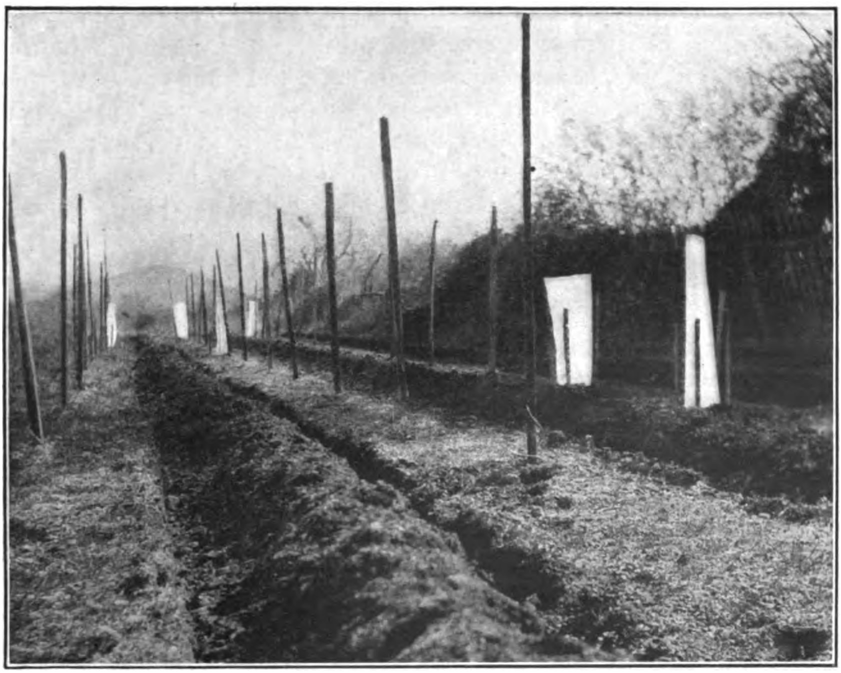

FIG. 1.—Field cages so placed as to catch any hop aphides that might emerge from eggs deposited upon the hop roots. (Original.)

Perkins, May 16, 1912. No winged migrants were observed at this time.

The first winged migrants were observed at Perkins on May 24, both on the prune and the hop, and in the latter case were only on the upper leaves, the lower leaves being entirely free.

Although field cages (fig. 1) which were placed over hopvines in February and removed after the surrounding vines were thoroughly infested did not contain any hop aphides, the fact that aphides were present on the hops before the winged migrants appeared and that they were found upon the lower leaves, while the winged forms

collect on the uppermost leaves, seems evidence enough to establish the hop as a winter host of the hop aphis, at least in these localities.

It has been thought possible that the hop aphis may hibernate upon some plants other than the plum, prune, sloe, and hop, and during this investigation many observations were made upon plants in the vicinity of the hops, for the winter eggs. While observing the winged migrants at Independence, Oreg., they were discovered upon cherry, alder, peach, and apple, and were found depositing young upon these plants.

In order to see if the young would mature on the cherry, some infested leaves were placed in covered jelly glasses and the leaves renewed each day. These insects matured on cherry as rapidly as on plum, but as there were no males present they died without depositing any eggs. Later observations upon the same trees at Independence, however, failed to reveal any eggs upon any but the plum, on which plant they were very numerous. Although no eggs were found on these trees, the fact that the aphides could grow to full size upon the cherry indicates that under some conditions this insect may hibernate on the various plants on which it was found at Independence.

## EMERGENCE FROM HIBERNATION.

Whether the eggs are laid upon the plum, prune, sloe, or hop, the aphides emerge about the same time. The exact date was not obtained, but judging from the fact that full-grown aphides were observed April 23, and allowing 13 days for growth, they must have emerged from the egg about April 10. Again, allowing 26 days for the two generations on the prune and May 24 as the date of the appearance of the first winged insects, the eggs must have hatched by April 28. This assumption corresponds very closely with data obtained at Richfield Springs, N. Y., in 1888 by Mr. Theodore Pergande, who observed the emergence of the aphides from eggs on April 5, 16, and 18 and May 10.

The insects which emerge from the sexual eggs are wingless viviparous females—"stem-mothers," so-called. They are $1\frac{1}{2}$ to 2 millimeters ($\frac{1}{18}$ to $\frac{1}{12}$ inch) in length, whitish green in color, and have rather long antennæ set on frontal tubercles, which are provided on the inner side with a tooth (see fig. 2). These toothed frontal tubercles are very characteristic of this species and serve well to identify it.

## METHOD OF REPRODUCTION.

These viviparous insects, instead of depositing eggs, as do the sexual generations which appear in the fall, give birth to living young by a process called "budding." These young may be readily seen protruding from the tip of the abdomen. This is also the method of

FIG. 1.—NYMPHS AND WINGED FORMS OF THE HOP APHIS (PHORODON HUMULI) ON HOP LEAVES. (ORIGINAL.)

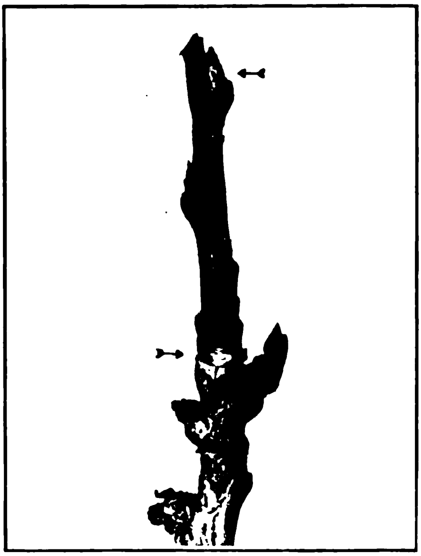

FIG. 2.—WINTER EGGS OF THE HOP APHIS. POSITION INDICATED BY ARROWS. (ORIGINAL.)

STAGES OF THE HOP APHIS.

reproduction of the winged migrants of both the spring and the fall generations. The stem-mothers are very prolific, as shown in Table III, one aphis being capable of populating several leaves in a very short time.

### NUMBER OF GENERATIONS ON ALTERNATE HOST.

Mr. Franz Remisch, of Saaz, Bohemia, who observed the emergence from the winter eggs, obtained two generations on plum. The writer did not observe the emergence of the first generation, but during the spring only two generations were found on prune, the second one being winged. In Bulletin 160 of the California experiment station Prof. W. T. Clarke reports the appearance of winged aphides 14 days after the first wingless insects were observed. This would be sufficient time for but one generation to mature, and it is very probable that there are only two generations upon the prune in the Pacific region.

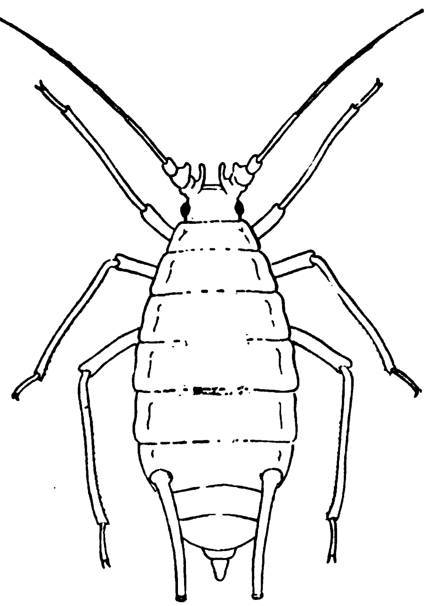

FIG. 2.—The hop aphis (*Phorodon humuli*): Wingless viviparous female. Greatly enlarged. (Original.)

### MIGRATING FORMS.

The winged or migrating aphides, except for the presence of two pairs of relatively large, delicate wings, some dark spots on the thorax, and a slightly more slender body (fig. 3 and Pl. I, fig. 1) differ little from the wingless form. They appeared at Perkins, Cal., May 15 and were present there and at Santa Rosa until June 15. Five belated individuals were observed at Perkins the latter part of July, but the migrations had taken place by the 20th of June.

### MIGRATORY ACTIVITIES.

These winged aphides, which mature on the plum, are the first migrants. They are weak fliers, but when aided by a light wind may travel some distance. Their progeny, the wingless viviparous females, which are the most common forms found upon the hopvines throughout the season, are incapable of migration from one vine to another except where two vines come into contact so that the aphis

can crawl from one to the other. The winged forms, therefore, are the only ones that migrate during the spring and early summer.

In the fall the winged form (fig. 3) that produces the sexual female migrates from the hop to its winter host—the plum, prune, sloe, or hop—and later the winged male migrates to the plant on which the sexual female awaits fertilization.

In the rearing cages and in the field during 1912 winged forms did not appear except as noted above. Winged forms were observed, however, developing upon the hopvines during the summer, at Watsonville, Cal., by Prof. W. T. Clarke, of the California Experiment Station, in 1902; by Mr. Franz Remisch, at Saaz, Bohemia; by Mr. H. N. Ord, at Independence, Oreg.; and by the writer at Santa Rosa, Cal., in 1911.

As previously stated, the winged migrants are weak fliers, but when aided by the wind may travel some distance. Some individuals were

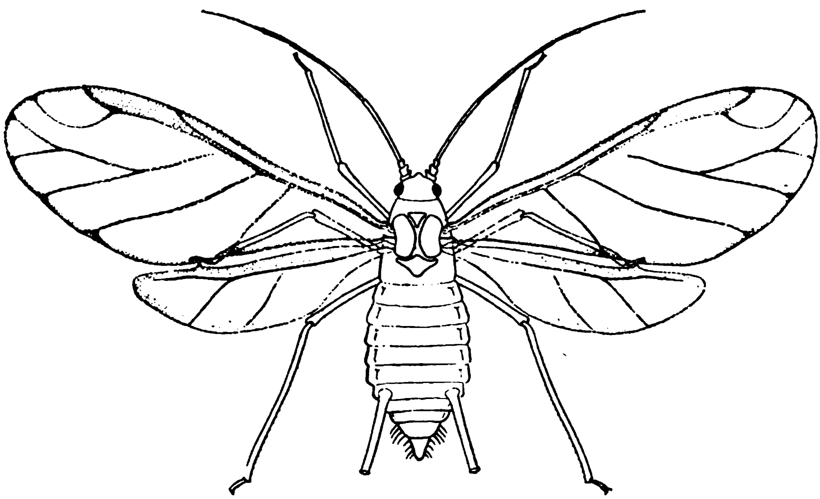

FIG. 3.—The hop aphis: Winged female migrant. Much enlarged. (Original.)

found half a mile from the infested prune trees. The infestation, however, decreases as the distance from the alternate host increases.

It was observed that more migrants collect upon the taller vines and the upper, newly expanded leaves of the other vines than upon the lower matured leaves. Very few winged aphides were observed on the fully expanded and hardened foliage, but were in every case some distance from the ground. The lower leaves were entirely free from the winged forms.

DEPOSITION OF YOUNG.

Upon reaching the hopvines these parthenogenetic migrants were observed giving birth to young, the number deposited by each individual varying between 1 and 8, as is shown in Table I.

TABLE I.—*Rate of deposition of young by winged migrants of the hop aphis from prune trees.*

| Became winged. | Date and number deposited. | | | | | | Total. |
|---|---|---|---|---|---|---|---|
| | May 28. | May 29. | May 30. | May 31. | June 1. | June 3. | |
| May 28 | 1 | 4 | 1 | 1 | | | 7 |
| Do | 2 | 2 | | | 1 | | 5 |
| Do | 1 | 3 | | | 1 | | 5 |
| Do | 2 | 4 | 1 | | 1 | | 8 |
| May 30 | | | | | 1 | | 1 |
| Do | | | | 2 | | 1 | 3 |
| May 31 | | | | | 1 | | 1 |
| Average | | | | | | | 4.3 |

The data in Table I were obtained by isolating nymphs, taken from the prune trees, upon clean prune leaves in covered jelly glasses. When the winged insect appeared it was immediately placed upon a hop leaf. The deposited young were removed daily.

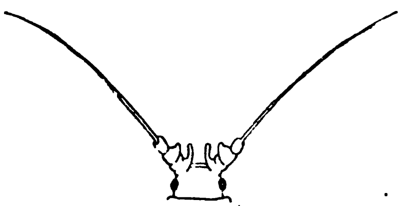

FIG. 4.—Head of hop aphis, showing frontal tubercles. Greatly enlarged. (Original.)

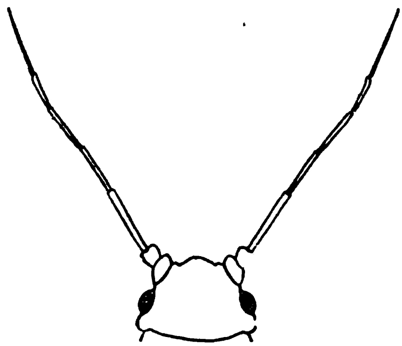

FIG. 5.—Head of melon aphis (*Aphis gossypii*). This aphis is frequently found on hops. Note differences in head from that of hop aphis. Greatly enlarged. (Original.)

These young deposited by the winged aphides are wingless parthenogenic insects (Pl. II, fig. 1). They have the characteristic frontal tubercles (see fig. 4, in comparison with fig. 5) and vary in color from watery white to green. The very young insects and those that have just molted are very light, while the older ones may be quite green.

## RATE OF GROWTH.

These young aphides grow very rapidly, molt four times, and immediately after the fourth molt commence depositing their young, as shown in Table II.

TABLE II.—*Stages in the development of the wingless viviparous female hop aphis.*

| No. | Deposited. | First molt. | Second molt. | Third molt. | Fourth molt. | Commenced depositing young. | Total days. |
|---|---|---|---|---|---|---|---|
| 1 | June 11 | June 13 | June 15 | June 17 | June 19 | June 20 | 9 |
| 2 | 15 | 17 | 20 | 23 | 25 | 27 | 12 |
| 3 | 15 | 18 | 21 | 23 | 26 | 27 | 12 |
| 4 | 16 | 19 | 21 | 23 | 25 | 27 | 11 |
| 5 | 18 | 21 | 23 | 26 | 28 | 29 | 12 |
| 6 | 18 | 22 | 24 | 26 | 28 | 29 | 12 |

From these experiments, which were conducted with individual insects, it was found that a period of from 8 to 12 days is required for the aphides to pass through the four molts and begin depositing young.

### NUMBER OF YOUNG DEPOSITED BY VIVIPAROUS FEMALES.

Some of the experiments that were carried on to determine the number of young that are deposited by individual aphides are recorded in Table III.

TABLE III.—*Number of young deposited by each of 12 individuals of the hop aphis.*

| Date. | Number of young deposited by— | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 1. | No 2. | No. 3. | No. 4. | No. 5. | No. 6. | No. 7. | No. 8. | No. 9. | No. 10. | No. 11. | No. 12. |
| June 12 | 4 | | | | | | | | | | | |
| 13 | 5 | | | | | | | | | | | |
| 14 | 7 | 4 | 1 | | | | | | | | | |
| 15 | 4 | 3 | 3 | | | | | | | | | |
| 16 | 7 | 2 | 3 | | | | | | | | | |
| 17 | 2 | 3 | 4 | | | | | | | | | |
| 18 | 4 | 3 | 5 | | | | | | | | | |
| 19 | 2 | 4 | 3 | | | | | | | | | |
| 20 | 0 | 4 | 5 | 1 | | | | | | | | |
| 21 | 3 | 2 | 4 | 1 | 1 | 2 | | | | | | |
| 22 | 4 | 8 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | | | |
| 23 | 0 | 3 | 3 | 4 | 3 | 3 | 2 | 3 | 4 | | | |
| 24 | 3 | 3 | 2 | 2 | 4 | 2 | 2 | 2 | 0 | | | |
| 25 | 5 | 3 | 2 | 5 | 3 | 8 | 4 | 3 | 4 | | | |
| 26 | 3 | 4 | 5 | 4 | 7 | 3 | 6 | 9 | 4 | | | |
| 27 | 3 | 4 | | 3 | 5 | 3 | 5 | 4 | 4 | 1 | | |
| 28 | 5 | 9 | | 6 | 2 | 3 | 5 | 7 | 7 | 4 | 2 | 3 |
| 29 | 4 | 3 | | 5 | 8 | 2 | 8 | 6 | 5 | 2 | 4 | 1 |
| 30 | 1 | 5 | | 2 | 2 | 3 | 4 | 0 | 5 | 1 | 1 | 7 |
| July 1 | 2 | 2 | | 6 | 1 | 5 | 4 | 7 | 6 | 3 | 8 | 5 |
| 2 | 0 | 3 | | 3 | 5 | 2 | 6 | 1 | 5 | 2 | 3 | 4 |
| 3 | 0 | 2 | | 3 | 3 | 6 | 5 | 2 | 4 | 4 | 2 | 6 |
| 4 | 0 | 3 | | 3 | 3 | 4 | 4 | 3 | 6 | 2 | 2 | 6 |
| 5 | | | | 2 | 6 | 0 | 4 | 3 | 3 | 4 | 4 | 5 |
| 6 | | | | | 6 | 6 | 2 | 6 | 9 | 4 | 0 | 4 |
| 7 | | | | | 4 | 7 | 3 | 4 | 7 | 3 | 1 | 3 |
| 8 | | | | | 1 | 2 | 4 | 2 | 5 | 1 | 1 | 1 |
| 9 | | | | | 3 | 3 | | 5 | 1 | 4 | 0 | 1 |
| 10 | | | | | 6 | 2 | | 1 | 3 | 1 | 1 | 0 |
| 12 | | | | | 5 | 2 | | 1 | 1 | 1 | | 2 |
| 13 | | | | | 4 | 5 | | 2 | 2 | 1 | | 2 |
| 14 | | | | | 2 | 2 | | | | | | 1 |
| 15 | | | | | 2 | 4 | | | | | | |
| 16 | | | | | 3 | 3 | | | | | | |
| 17 | | | | | | 2 | | | | | | |
| 18 | | | | | | 1 | | | | | | |
| Total | 68 | 77 | 43 | 53 | 92 | 87 | 70 | 73 | 87 | 38 | 29 | 51 |

In order to obtain the foregoing data nearly mature aphides were isolated on hop leaves in tin-covered jelly glasses. The leaves were changed daily and the aphides which had been deposited were removed. The number of young which are deposited by one stem-mother were thus found to be from 29 to 92, with an average of 64 for the 12 aphides under observation. The length of life of these aphides varied from 25 to 38 days, with an average of 30.75 days. Thus an aphis living an average life of 30.75 days, depositing an

average number of young (3.3 per day) over an average period of 19 days, would give birth to 63 aphides.

At this rate of reproduction, provided that none of the aphides were destroyed before they had lived an average life, one winged aphis which settles on the hop in the spring would at the end of the fifth generation be the parent of 4,068,989,826 living aphides. These aphides would weigh 2,152 pounds. From these figures the very sudden and extensive infestations by this insect are readily explained.

### THE FALL MIGRANTS.

The nymphs of the fall migrants (fig. 6) became winged in the breeding cages at Perkins, Cal., on August 26 and in the field August 28. Migrants were observed upon plum at Independence, Oreg., September 22, 1912. Young were being deposited there and upon the next visit to the locality, October 16, large numbers of male aphides were observed copulating with the sexual females that had been deposited by the migrants. Many eggs were also present at this time.

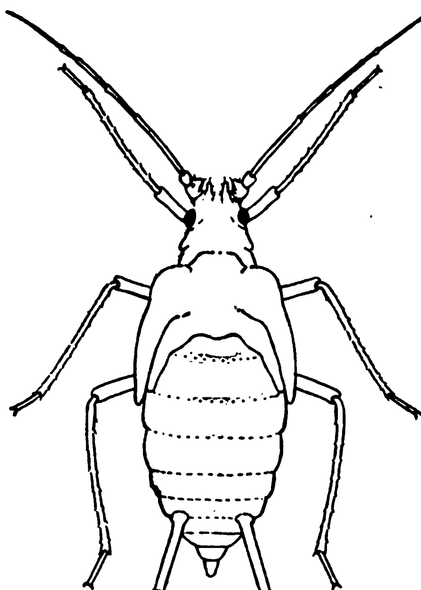

FIG. 6.—The hop aphis: Nymph, showing wing-pads. Greatly enlarged. (Original.)

### THE WINTER EGG.

The winter egg, when first deposited, is a shiny-green object, ovate in shape, and a little smaller than the head of a pin ($\frac{3}{4}$ mm. in length). Soon, however, it turns dark green and then black and appears as a shiny-black point (Pl. I, fig. 2) on the branch of the alternate host plant.

The eggs are usually deposited close around the buds or on the rough leaf scars, but may sometimes be found upon the smooth parts of the twigs.

### THE LIFE CYCLE.

The entire life cycle where the writer's observations were made is as follows: Two generations occur on the alternate host, the second one being winged. Five and six generations occur on the hop, a part of the fifth becoming winged and depositing young upon the

alternate host, and part being wingless and depositing young (sixth generation) upon the hop, producing the male aphides which fly to and copulate with the young deposited on the alternate host by the winged individuals of the fifth generation. These fertilized females deposit the winter eggs, which, hatching in the following spring, produce the viviparous insects for that season.

Table IV gives one series of dates for the life cycle. This series will vary according to the date of the emergence of the first generation from the egg in the spring. The variation in the date of hatching of the winter eggs causes an overlapping of generations, so that these are not in the least distinct.

TABLE IV.—*Life cycle of the hop aphis as observed at Perkins, Cal., in 1912.*

| | |
|---|---|
| Emergence from eggs | June 3 |
| Appearance of second generation, winged | June 17 |
| Appearance of third generation (first on hops) | June 30 |
| Appearance of fourth generation (second on hops) | July 11 |
| Appearance of fifth generation (third on hops) | July 22 |
| Appearance of sixth generation (fourth on hops) | Aug. 2 |
| Appearance of seventh generation (fifth on hops), part winged | Aug. 15 |
| Appearance of eighth generation (sixth on hops), males | Aug. 25 |
| Appearance of eighth generation, sexual females, on plum | Aug. 25 |
| Deposition of eggs | Sept. 14 |

In the report of the Department of Agriculture for 1888, Prof. C. V. Riley gives the following data upon the life history, which vary somewhat from the data given in this bulletin:

> Three parthenogenic generations are produced upon Prunus, the third being winged. * * * A number of parthenogenic generations are produced upon the hop until in autumn, and particularly during the month of September winged females are again produced.

This account is also at variance with the writer's own observations in that no winged forms are noted during the summer.

## THEORY REGARDING SUMMER MIGRANTS.

The presence of winged forms of the hop aphis throughout some seasons and the absence of such forms during 1912, both in the laboratory and in the field, except at the end of the fifth generation, are explained as follows: The eggs of the hop aphis have been observed to hatch individually during a period of one month and five days, April 5 to May 10. The winged forms were observed beginning to migrate from the prune May 24, and migration was not completed until June 20. Thus until the 20th of June migrants from the alternate host (the plum or hop) were present in the hopyards. Beginning the life cycle with the first insects that migrated, the seventh or winged generation on the hop would be mature July 19. These insects, finding some tender hop leaves upon which to settle,

would deposit young thereon. The deposited young, because of climatic and succulent food conditions, might become viviparous instead of oviparous, causing a continuous increased infestation of the hopvines.

At Perkins and Santa Rosa, Cal., in 1912, a hot, dry wind early in the season destroyed practically all of the aphides which came from the alternate host, and it was the progeny of the later migrants which became winged.

These data have not been proven, but remain as the only explanation of the presence of winged aphides between the spring and fall migrations.

Since the first insects that migrate to the hop are probably the progenitors of the winged forms that occur during midsummer, it is evident that the control of the aphis early in the season will tend to reduce the numbers of the winged insects and therefore lessen the chance that thoroughly sprayed yards will become reinfested.

## HABITS.

### HABITATION.

Hop aphides are usually found on the underside of the leaves (Pl. II, fig. 1), but in cases of severe infestation they may be found on the upper surface as well. They gradually work up the vines, and when the hops have formed many of them may be observed inside of the cones.

### PROTECTION.

Many of the aphides, especially in cases of slight infestation, will be found close to the veins and in the hollow parts of the leaves. Here, besides being protected by the sheltering leaf, they are partially protected by the surrounding wall of leaf. Other than the natural formations of the leaves the hop aphis has no protection from wind, rain, or enemies.

### RELATION OF ANTS TO THE HOP APHIS.

At Perkins, and especially at Santa Rosa, Cal., a large black ant, *Formica subsericea* Say, was continually observed among the aphides. The habit of the ants in caring for plant lice that they may feed upon the honeydew excreted by them is historical. These ants carry the aphides to the newly expanded leaves, thus spreading the infestation. They were so active at Santa Rosa that it was found necessary to put tree tanglefoot on the vines that were used for the experiments, to prevent the ants from reinfesting them.

### FIRST APPEARANCE OF THE HOP APHIS IN THE SEASON.

The first wingless viviparous aphides of the season at Santa Rosa, Cal., at Independence, Oreg., and at Agassiz, British Columbia, were invariably observed upon hopvines near shrubby growth bordering a watercourse or fence, near a sheltering tree, or near buildings. At Santa Rosa and Agassiz, where the writer made observations during the early part of the season, the aphides were most numerous near shrubbery or buildings, the numbers decreasing as the center of the field was approached. This condition is shown diagrammatically in figure 7. In fact, at Santa Rosa on May 30, 1911, and June 6, 1912, the aphides occurred in numbers only near the brush, trees, or buildings, the other parts of the field being almost entirely free.

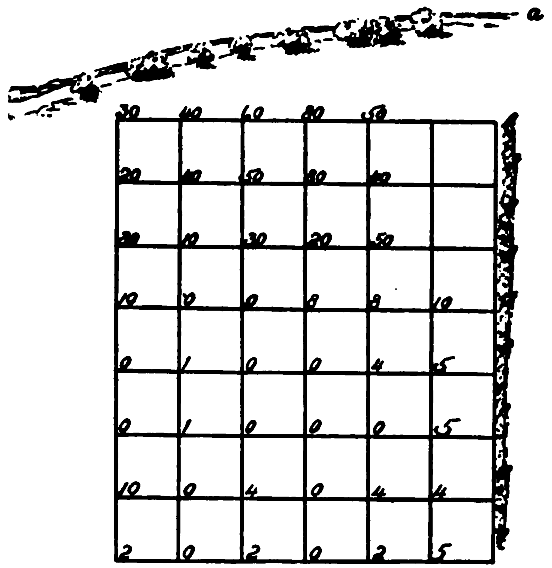


FIG. 7.—Diagram showing relative number of aphides in different parts of a single hopyard, indicating the increased infestation near Santa Rosa Creek (*a*). (Original.) (The numbers represent approximate counts of aphides which were present on the vines June 1, 1911. On September 1 these vines were grossly infested. The row nearest the creek (*a*) is row 1; the next is row 2; and after that the numbers were taken from every fifth row. Each number represents the number of aphides found on the hill in that location.)

### FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE APHIS.

Moderately warm, moist seasons with an occasional rain but with little strong wind are the most favorable for the development of the hop aphis, and the most severe infestations occur during seasons of such weather.

A hot, dry wind is very unfavorable to the aphides and in some sections, when followed by dry, warm weather, will materially check infestation.

### EFFECT OF HEAT.

Some careful observations on the condition of the hop aphis after continued hot weather, and especially when the hot weather was accompanied by a north wind, were made at Perkins, Cal.

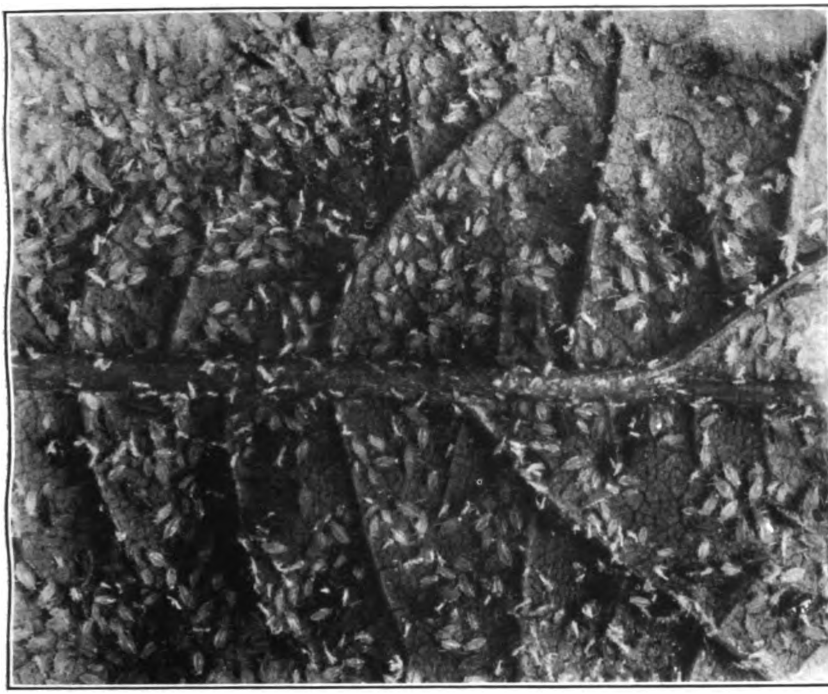

FIG. 1.—WINGLESS PROGENY OF WINGED HOP APHIDES FROM ALTERNATE HOST. (ORIGINAL.)

FIG. 2.—WILLOWS ALONG EDGE OF HOPYARD, WHICH WERE ERRONEOUSLY SUPPOSED TO HARBOR HOP APHIDES. (ORIGINAL.)

THE HOP APHIS.

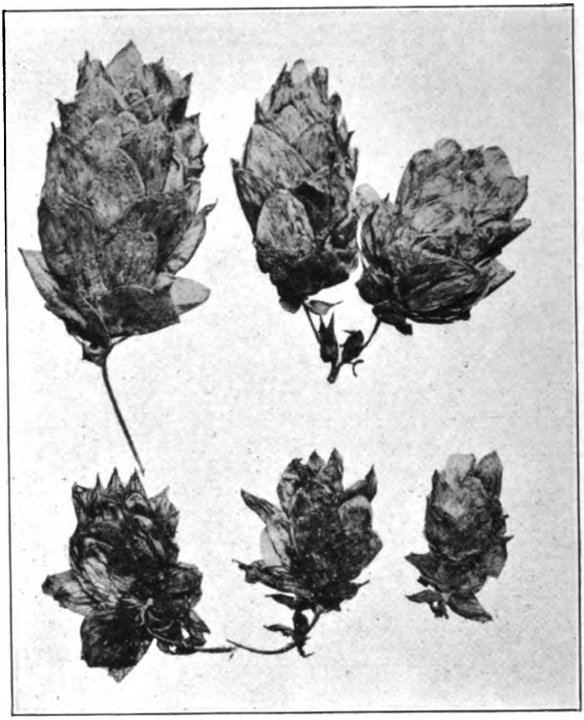

FIG. 1.—UPPER ROW, NORMAL HOP CONES; LOWER ROW, HOP CONES INJURED BY THE HOP APHIS. (ORIGINAL.)

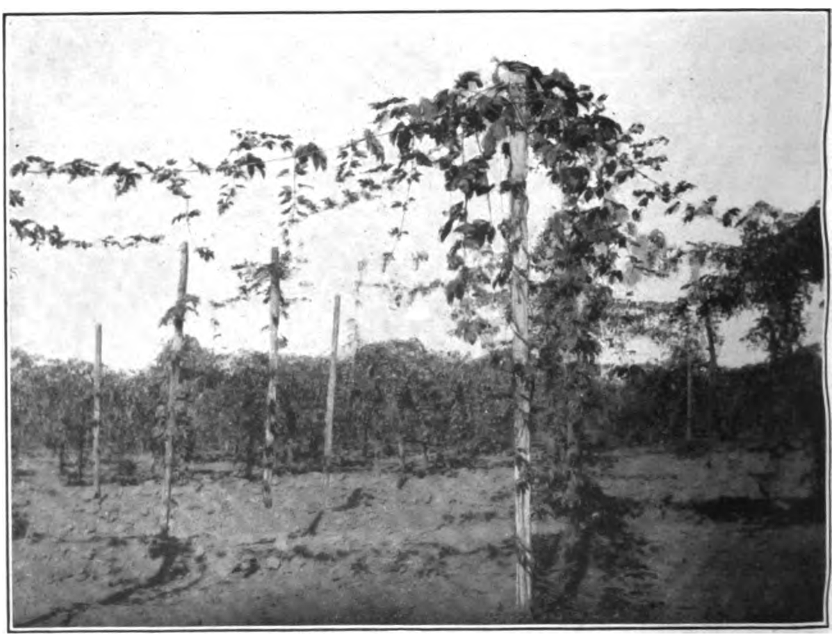

FIG. 2.—VINES IN FOREGROUND SEVERELY INJURED BY THE HOP APHIS SHOWING LACK OF GROWTH AS COMPARED WITH UNINJURED VINES IN THE DISTANCE. (ORIGINAL.)

INJURY TO HOPS AND HOPVINES BY THE HOP APHIS.

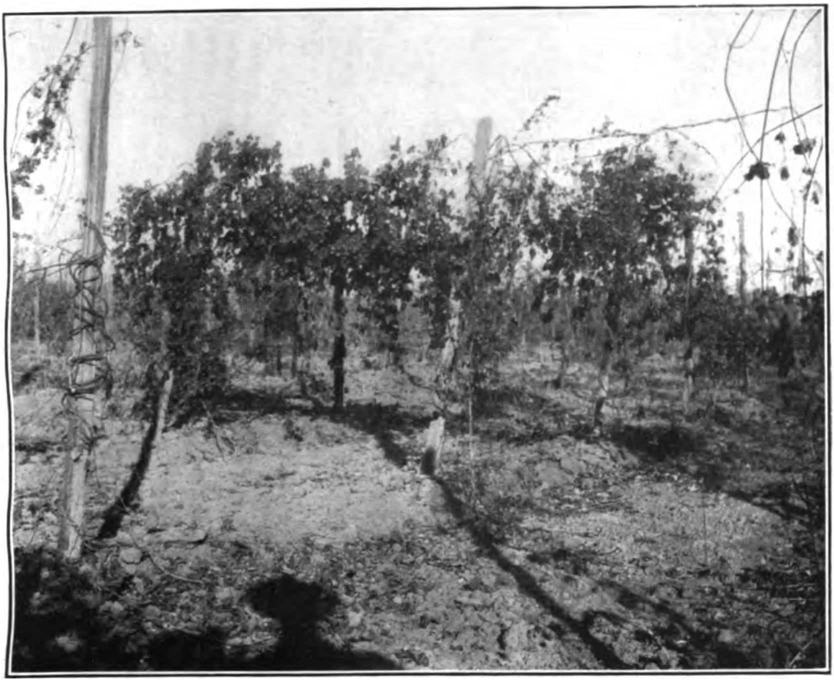

FIG. 1.—HOPVINES SEVERELY INJURED BY THE HOP APHIS, AND LEFT IN THE FIELD. (ORIGINAL.)

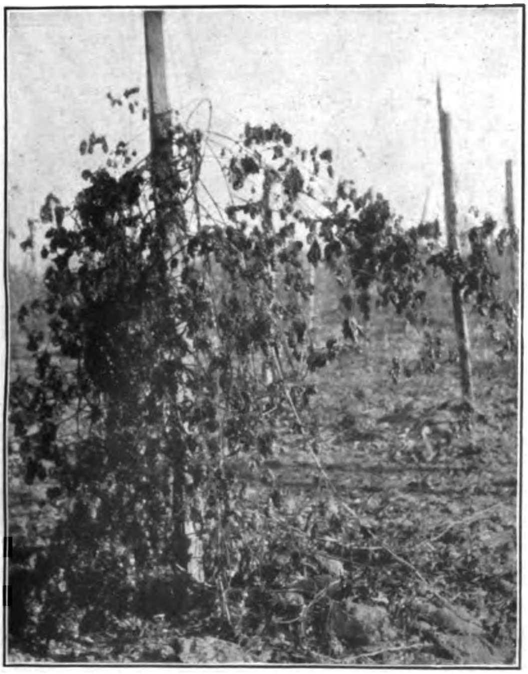

FIG. 2.—ENLARGED VIEW OF DAMAGED AND MOLDY HOPVINES. (ORIGINAL.)

INJURY TO HOPVINES BY THE HOP APHIS.

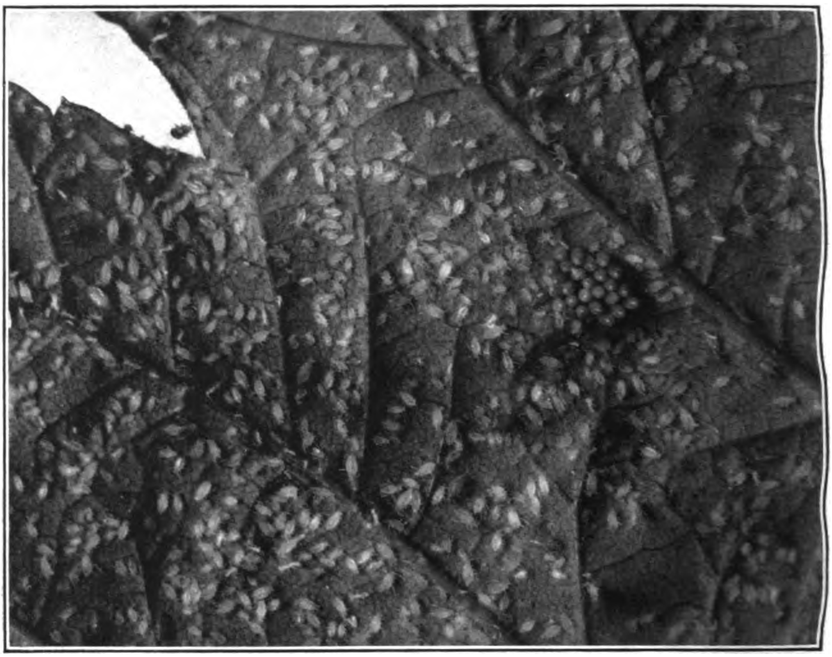

FIG. 1.—EGGS OF HIPPODAMIA CONVERGENS AMONG HOP APHIDES ON LEAF. (ORIGINAL.)

FIG. 2.—SYRPHUS FLY LARVÆ FEEDING UPON THE HOP APHIS. (ORIGINAL.)

SOME NATURAL ENEMIES OF THE HOP APHIS.

It was noticed that in every case where the aphides were reduced by the effect of the heat, some small ones remained and upon maturing produced the following generation. In some cases not a single full-grown aphis was found after the hot weather had ceased, but many of the young aphides were present upon the vines. A similar observation was made at Santa Rosa, Cal.

## FOOD PLANTS.

*Phorodon humuli* feeds principally upon the hop. It has, however, some alternate food plants on which the sexual forms develop. (See p. 14.)

It is a common belief that the aphides found upon the shrubs and trees growing near the hopyards (see Pl. II, fig. 2) are hop aphides and that they later migrate to the hops. Specimens of aphides were taken from various plants growing near the hopyards at Agassiz, British Columbia, Independence, Oreg., and Santa Rosa, Cal., and identified. In no case was *Phorodon humuli* found among the aphides collected. Even though aphides may be extremely numerous upon such near-by plants, they do not in the least menace the hop crops; hence their destruction, from the standpoint of hop-aphis control, is unnecessary.

## NATURE OF DAMAGE.

### GENERAL EFFECT OF APHIDES UPON HOPS.

The hop aphis injures the crops in two ways: By extracting the plant juices it prevents the normal growth of the plant, and by the excretion of honeydew, on which grows the black-smut fungus, *Cladosporium* sp., it injures the quality of the crop.

In one hopyard at Santa Rosa, Cal., May 31, 1911, several vines were found which were severely infested. Later in the season these vines were observed to have made little growth. The few hop cones which had formed were very small, some being only slightly larger than the burrs. Plate III, figure 1, shows some of these small cones compared with normal cones which were taken from near-by uninfested vines. The relatively small growth of the infested vines compared to that of the uninfested vines is well illustrated in Plate III, figure 2. The vines in the foreground were severely injured by the aphides, while those farther back were only slightly infested until late in the season and made a very fair growth.

Some vines that were only slightly infested were observed throughout the season. These vines grew well and bore a fine crop of hops, but just before the harvest the aphides entered the cones, extracted their vitality, and covered the scales with honeydew, in which the black-smut fungus soon established itself. These cones were so

severely injured that they were not worth picking, and they were left in the field. (See Pl. IV, figs. 1, 2.)

Where control work is attempted the infestation seldom becomes so severe as to retard the growth of the vines, and it is the late injury—the accumulation of honeydew upon the cones and the resulting growth of the black fungus—which is most to be feared.

### HONEYDEW AND ITS EFFECT ON THE HOPS.

Honeydew is a substance which is excreted from the anal opening of the aphides. It is composed largely of gums and sugar and is sticky and sweet to the taste. On warm afternoons it may be seen falling as a mist from severely infested vines.

Hops covered with honeydew are sticky, do not have the normal amount of crispness, and when pressed between the fingers remain flattened out. Honeydew may under some circumstances increase the weight of the crop. One grower estimated that he made $1,000 on honeydew in 1911. However, the quality of the crop was greatly injured, and had the demand for hops been less the grower would not have been able to sell, and his crop would have been a complete loss.

Even though under certain uncontrollable circumstances the presence of honeydew may increase the income from a crop of hops, their quality is injured, and the honeydew is the medium for the black-smut fungus, which will, in ninety-nine cases out of one hundred, so injure the quality of the crop that it will be unsalable.

### BLACKENING OF HOPS.

Neither the honeydew nor the aphides are directly responsible for the blackening of the hops. The blackening is due to a smut fungus (*Cladosporium* sp.) commonly called "mold," which grows upon the honeydew. If the honeydew happens to be upon the hop cones, this fungus gives the hops a black, moldy appearance, which is extremely undesirable.

### NATURAL ENEMIES.

Several predaceous insects have been observed attacking the hop aphis at Perkins and at Santa Rosa, Cal. The ladybirds *Hippodamia convergens* Guér., *Coccinella californica* Mannh., *Coccinella abdominalis* Say, and *Chilocorus orbus* Cas. were frequently found among the aphides. Some eggs of *Hippodamia convergens* deposited among the hop aphides are shown in Plate V, figure 1. *Chrysopa californica* Coq. was always abundant in the hop fields, and the larvæ were very active in feeding upon the aphides.

The larvæ of syrphus flies (Pl. V, fig. 2) were abundant in the hopyards. *Syrphus opinator* O. S. and *Syrphus americanus* Wied. were reared from the larvæ which were collected from hop leaves.

A small predaceous bug, *Triphleps insidiosus* Say, was occasionally observed among the aphides.

The following insects were observed by Mr. Theo. Pergande attacking the hop aphis at Richfield, N. Y., in 1887:

| | |
|---|---|
| *Triphleps insidiosus* Say | *Camptobrochis nebulosus* Uhl. |
| *Adalia bipunctata* L. | *Anthocoris* sp. |
| *Stethorus punctum* Lec. | |

Parasites and predaceous insects destroy large numbers of hop aphides, but in no case have they been observed successfully to control an infestation.

## CONTROL OF THE HOP APHIS.

### AXIOMS OF SUCCESSFUL CONTROL.

In the economic control of the hop aphis, as of other insect pests, there are certain underlying principles which must be adhered to if the work is to be entirely successful.

(1) All of the machinery to be used must be capable of doing effective work and must be in good working condition prior to the time at which spraying should commence.

(2) Spraying must commence at the proper time; it must not be put off.

(3) The material used must be carefully prepared and thoroughly but not wastefully applied.

These are fundamental principles, and control work will be less effective and more costly if they are not closely adhered to.

### INSECTICIDES USED.

Several contact insecticides have been used to control the hop aphis. The most extensively used sprays, however, are tobacco decoctions with whale-oil soap and quassia chips with whale-oil soap. In order to obtain exact data upon the effectiveness of these materials upon the hop aphis a series of experiments on a small scale was conducted at Santa Rosa, Cal., and notes were taken from experiments made on a large scale in Oregon. Tag counts were made; i. e., 20 tags were tied to as many leaves, and records of the number of aphides on the leaves before and three days after spraying were made on the tags; the percentage of aphides killed was thus accurately obtained.

### TIME TO BEGIN SPRAYING.

It is very desirable to spray all plums or prunes that are infested by hop aphides as soon as the infestation is observed, both in the fall and in the spring. This will check the migration and lessen the infestation of the hops. The hops, however, should be sprayed as soon as the

aphides become numerous. This is usually from June 1 to 15, though in some cases it may be earlier. It is well to spray first the fields which are most seriously infested.

It is usually desirable to wait until the vines are stripped before spraying.

### NUMBER OF APPLICATIONS.

The number of applications which are necessary to control the aphides will vary with the seasonal and local conditions. The object is to prevent injury to the vines and to have the vines practically free of aphides at the time hop picking commences. To obtain good results it is usually necessary to spray the vines from two to four times.

### NECESSITY FOR EARLY SPRAYING.

Mr. H. N. Ord, who directed some very successful spraying operations in a large hopyard in Oregon, claims that the secret of his success was early spraying. He began before the aphides became very numerous and continued as long as there were any aphides in the field. Yards sprayed under Mr. Ord's direction were practically free from aphides, while the crops of a near-by grower were so severely damaged that 10 acres were left in the field unpicked.

### NECESSITY FOR THOROUGH WORK.

The insecticides which are used for the hop aphis kill only by actual contact, and if satisfactory results are to be obtained it is absolutely necessary that the spray be thoroughly applied. Running the spray up and down the vine is not sufficient, because all of the leaves must be thoroughly wetted on both surfaces if good results are to be obtained.

### PROCRASTINATION.

In sections where the aphides are frequently controlled by weather conditions some growers are likely to delay control work, hoping that a hot, dry wind will relieve them of the necessity of spraying. In one hop-growing section of California such a wind has appeared regularly for several years, but during the past two seasons (1911–12), which were favorable for the aphides, it did not arrive. Many growers, depending upon this wind, made no effort to control the aphides until late in the season, when much damage had been done. It was then difficult to make much progress against the insects, and severe injury resulted.

### SPRAYING EXPERIMENTS.

The nicotine solutions appeared to be the most promising materials and were therefore the most extensively used in the experiments. The following tables, arranged according to relative costs,

show the results of these experiments and give the cost of the materials per 100 gallons of spray:

TABLE V.—*Results of spraying experiments for the hop aphis, with costs of materials per 100 gallons of spray.*

| Experiment No. | Materials used. | Pressure. | Number of aphides. | Per cent killed. | Date sprayed. | Date counted. | Cost per 100 gallons. |
|---|---|---|---|---|---|---|---|
| | | *Pounds.* | | | | | |
| 1 | Nicotine sulphate, 1 to 3,000 | 80–100 | 1,227 | 99.9 | June 15 | June 17 | $0.416 |
| 2 | Nicotine sulphate, 1 to 2,000 | 80–100 | 1,005 | 97.8 | June 13 | ...do... | .62 |
| 3 | Nicotine sulphate, 1 to 3,000; whale-oil soap, 4 to 100. | 80–100 | 3,089 | 99.2 | June 14 | ...do... | .80 |
| 4 | Nicotine sulphate, 1 to 3,000; cresol soap, 1 to 300. | 80–100 | 1,990 | 95 | June 15 | ...do... | .83 |
| 5 | ...do... | 80–100 | 3,474 | 84 | ...do... | ...do... | .83 |
| 6 | Blackleaf tobacco, 1 to 75 | 80–100 | 1,810 | 94 | ...do... | ...do... | .86 |
| 7 | Nicotine sulphate, 1 to 2,000; cresol soap, 1 to 300. | 80–100 | 2,320 | 97 | ...do... | ...do... | 1.04 |
| 8 | Blackleaf tobacco, 1 to 60 | 80–100 | 2,590 | 99.8 | ...do... | ...do... | 1.08 |
| 9 | Nicotine sulphate, 1 to 1,000 | 80–100 | 654 | 98.2 | June 13 | ...do... | 1.25 |
| 10 | Nicotine sulphate, 1 to 2,000; lye-resin soaps. | 80–100 | 2,225 | 99.1 | June 15 | ...do... | 1.37 |
| 11 | Nicotine sulphate, 1 to 1,000; whale-oil soap, 4 to 100. | 80–100 | 2,512 | 99.4 | June 14 | ...do... | 1.42 |
| 12 | Nicotine sulphate, 1 to 1,000; cresol soap, 1 to 300. | 80–100 | 2,780 | 99 | June 15 | ...do... | 1.67 |
| | **INEFFECTIVE MATERIALS.** | | | | | | |
| 13 | Lime sulphate, 36° Baumé, 1 to 86. | 80–100 | 1,950 | 14 | June 16 | June 19 | $0.24 |
| 14 | Cresol soap, 1 to 300 | 80–100 | 129 | 0 | June 13 | June 16 | .42 |

From the data in Table V it is evident that all the experiments except Nos. 5, 13, and 14 were quite satisfactory and that Nos. 1, 2, 3, and 4 were the cheapest materials to use. It was found that the nicotine sulphate without soap did not spread very readily and that the good results obtained were due to the very careful application. Either flour paste or soap should always be used with the nicotine solutions.

TABLE VI.—*Spraying experiments conducted in Oregon against the hop aphis during 1911.*

| Experiment No. | Materials used. | Pressure. | Number of aphides. | Per cent killed. | Date sprayed. | Date counted. | Cost per 100 gallons. |
|---|---|---|---|---|---|---|---|
| | | *Pounds.* | | | | | |
| 1 | Tobacco waste, 25 pounds to 100 gallons water. | 100 | 213 | 100 | Aug. 22 | Aug. 25 | $0.18 |
| 2 | Tobacco waste, 27½ pounds to 100 gallons water. | 100 | 253 | 100 | ...do... | Aug. 24 | .20 |
| 3 | Nicotine sulphate, 1 to 2,000 | 100 | 695 | 89 | Aug. 21 | Aug. 23 | .62 |
| 4 | Nicotine sulphate, 1 to 2,000; whale-oil soap, 5 to 100 | 100 | 529 | 98 | ...do... | ...do... | .845 |
| 5 | Nicotine sulphate, 1 to 1,000 | 100 | 73 | 100 | ...do... | ...do... | 1.25 |
| 6 | Nicotine sulphate, 1 to 2,000; whale-oil soap, 5 pounds to 100 gallons water | 100 | 491 | 98 | ...do... | ...do... | 1.475 |
| 7 | Nicotine sulphate, 1 to 750 | 100 | 130 | 97 | Aug. 22 | Aug. 25 | 1.66 |

Table VI represents the work done in Oregon by Mr. H. N. Ord and is in part a repetition of the results recorded in Table V. It also contains data upon tobacco waste, which appears very satisfactory and very cheap. If the decoction is allowed to boil or the tobacco happens to be low in nicotine, the spray will not be effective, and the vines will have to be resprayed.

If this material be used each tankful should be tested upon some aphides and a record of efficiency kept. It is for these reasons not so satisfactory as a material containing a known quantity of insecticide.

*Nicotine-sulphate formulas for 100-gallon lots.*

| | Ounces. |
|---|---|
| Nicotine sulphate, 1 to 1,000 | 13 |
| Nicotine sulphate, 1 to 2,000 | 6½ |
| Nicotine sulphate, 1 to 2,500 | 5¼ |
| Nicotine sulphate, 1 to 3,000 | 4½ |

The formula "4–100," given for flour paste, means 4 gallons of flour paste (made according to directions) to each 100 gallons of spray. This paste contains 1 pound of flour in each gallon, so that there would be 4 pounds of flour (in the form of paste) in each 100 gallons of spray.

The formula "4–100," when referring to whale-oil soap, means 4 pounds of whale-oil soap to 100 gallons of spray.

Flour paste had proved to be a most efficient, cheap, and convenient spreader for the lime-sulphur solutions.[1] Some experiments were conducted during 1912 with this material in combination with nicotine sulphate against the hop aphis. Table VII gives some of the results obtained with this mixture.

TABLE VII.—*Experiments in the control of the hop aphis by sprays of nicotine sulphate and flour paste.*

| Formula. | Number of aphides present. | Per cent killed. | Cost per 100 gallons. |
|---|---|---|---|
| Nicotine sulphate, 1-2,000; flour paste, 4-100 | 627 | 100 | $0.71 |
| Nicotine sulphate, 1-2,500; flour paste, 4-100 | 611 | 100 | .60 |
| Nicotine sulphate, 1-3,000; flour paste, 4-100 | 1,668 | 99 | .50 |
| Do | 148 | 99 | .50 |
| Nicotine sulphate, 1-3,500; flour paste, 4-100 | 308 | 100 | .45 |
| Nicotine sulphate, 1-4,000; flour paste, 4-100 | 271 | 96 | .40 |

From the results noted in the preceding tables it is evident that nicotine sulphate is effective in dilutions as high as 1–3,500, and that flour paste, 4–100, is an effective spreader for this material. The nicotine sulphate, 1–4,000, was not quite so effective, and it was also observed that its action was so slow that the sprayed aphides were able to deposit young on the leaves, thus reinfesting the hopvines.

[1] See Bulletin No. 117 and Circular No 166 of this bureau.

Nicotine sulphate, 1–3,000 and 1–3,500, in combination with whale-oil soap or flour paste has been successfully used in experiments, but it would be safer in practice to use the lower dilutions. In case the greater dilutions are used, careful observations should be maintained to be sure that the spray is doing effective work. The nicotine preparations which come in cans have a slight tendency to settle. In case they do settle and are not thoroughly mixed before measuring, the percentage of active insecticide used in one lot of spray may be enough less than should be present in a uniform portion to render the spray ineffective. It is advisable, therefore, to be sure that these preparations are thoroughly mixed before measuring.

### MIXING NICOTINE SOLUTIONS AND WHALE-OIL SOAP.

During certain spraying experiments with tobacco extracts and whale-oil soap some difficulty was experienced in mixing the concentrated solutions of blackleaf tobacco and whale-oil soap. When these were combined a greenish-gray precipitate of a flocculent nature was formed. A similar precipitate occurred when one of the materials was diluted and the other left concentrated. When each solution was diluted to half of the final amount, however, this objectionable nozzle-clogging precipitate did not appear.

Flour paste does not have this effect, but when whale-oil soap is used as a spreader for tobacco sprays, both solutions *must* be well diluted before mixing.

### PREPARATION OF THE FLOUR PASTE.

In preparing the flour paste, mix a cheap grade of wheat flour with *cold* water, making a thin batter without lumps, or wash the flour through a wire screen with a stream of cold water. Dilute until there is 1 pound of flour in each gallon of mixture. Cook until a paste is formed, stirring constantly to prevent caking or burning. (See Pl. VI, fig. 1.) Add sufficient water to make up for evaporation.

If the paste is not sufficiently cooked, the resulting spray will not be effective. If overcooked, the paste will harden when thoroughly cool; it will then not mix with water very readily. Usually, however, the paste is used as it is prepared, and overcooking is not a disadvantage.

When mixed in a spray tank flour paste has a tendency to settle, and in order to do satisfactory work *agitation is necessary.* This is only a slight disadvantage, however, and is necessary with most spray materials. The large spray tanks are usually fitted with an agitator, and a hoe makes an effective agitator for the 50-gallon barrels, so that this problem is a simple one.

### ADVANTAGES OF FLOUR PASTE OVER WHALE-OIL SOAP AS A SPREADER FOR CONTACT INSECTICIDES.

Flour paste costs 8.8 cents per 100 gallons of spray. Cheap flour is always available, and the paste has no odor. Whale-oil soap costs 20 cents per 100 gallons of spray, is not always available, and has a disagreeable odor.

Both materials have to be heated before using.

The neutrality of flour paste was proven by the fact that when applied upon the foliage and blossoms of the hop, in proportions as high as 12 gallons of paste to 100 gallons of spray, no injurious effects resulted. When sprayed upon the hop burrs and delicate hop cones, it did not prevent pollination or injure the appearance of the scales.

### QUASSIA.

Quassia is the extract from the wood of *Picræna excelsa*, a tree occurring in Jamaica and containing the alkaloid quassin ($C_{32}H_{42}O_{10}$) in the form of crystalline rectangular plates. Quassia chips contain no tannic acid.

#### EFFECT OF QUASSIA ON APHIDES.

A solution of quassia containing the extract from 5.33 ounces of quassia chips in 1 quart of water was diluted one-half and sprayed on *Hyalopterus pruni* on prune. It was found necessary to wash the waxy pulverulence from the insects before they could be wetted. The leaves were tagged with the numbers of aphides present and the twigs set into water in the laboratory. A check branch was sprayed with pure water. That the strong quassia solutions have a decided insecticidal value is shown by the following data:

Aphides present before spraying, 37, 40, 109, 92, 190, 75, 140, 40; total, 723.
Aphides present after spraying, 0, 30, 3, 1, 0, 25, 0, 0; total, 59.
Per cent killed, 92.

Quassia solution at the rate of 7 pounds of chips to 250 gallons of water was applied to the aphides with the following results:

Aphides present before spraying, 48, 60, 30, 40, 73, 30, 200, 100, 63, 128, 12; total, 784.
Aphides present after spraying, 0, 0, 5, 0, 0, 0, 1, 2, 7, 9, 10; total, 34.
Per cent killed, 96.

The aphides on sprayed leaves turned brown when dead. The check leaves contained living insects only.

FIG. 1.—HINDU LABORER COOKING FLOUR PASTE. (ORIGINAL.)

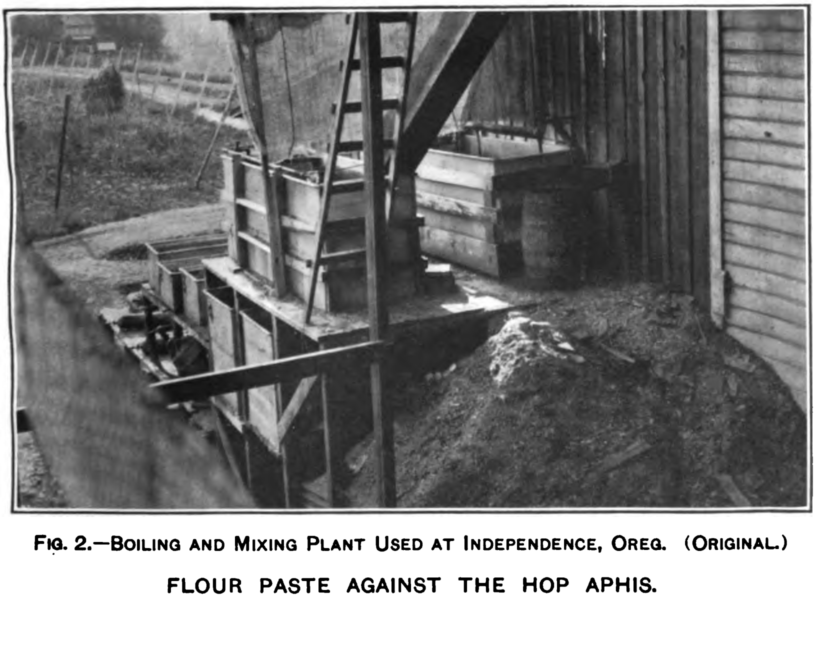

FIG. 2.—BOILING AND MIXING PLANT USED AT INDEPENDENCE, OREG. (ORIGINAL.)

FLOUR PASTE AGAINST THE HOP APHIS.

### THE USE OF QUASSIA.

Various formulas for quassia spray are used in the field and were observed to be effective when properly prepared. Some of them are as follows:

*Formula No. 1.*

| | Cents. |
|---|---|
| Quassia chips, 7 pounds, at 5¼ cents per pound | 37 |
| Whale-oil soap, 9 pounds, at 4½ cents per pound | 40.5 |
| Water, 250 gallons. Total cost per 100 gallons | 31 |

*Formula No. 2.*

| | Cents. |
|---|---|
| Quassia chips, 8 pounds, at 5¼ cents per pound | 42 |
| Whale-oil soap, 6 pounds, at 4½ cents per pound | 27 |
| Water, 100 gallons. Total cost per 100 gallons | 69 |

*Formula No. 3.*

| | Cents. |
|---|---|
| Quassia chips, 9 pounds, at 5¼ cents per pound | 47.2 |
| Whale-oil soap, 6 pounds, at 4½ cents per pound | 27 |
| Water, 100 gallons. Total cost per 100 gallons | 74.2 |

Formula No. 1 was used by Prof. W. T. Clarke in his work upon the hop aphis at Watsonville, Cal., in 1902. It was also successfully used by the writer in some field experiments at Santa Rosa, Cal., during 1911. The other formulas are stronger and have also been observed to be effective when properly prepared.

### PREPARATION.

Many failures in control work, when quassia is used, are due to faulty preparation of the material. Some growers only soak the chips and use what soaks out. Others boil them without previous soaking. The proper way to prepare quassia spray, based on Formula No. 1, is as follows:

Soak the chips 24 hours, then boil for 2 hours in 3 gallons of water. Add this decoction to 247 gallons of water in which the soap has been dissolved. The whale-oil soap is readily dissolved by boiling in a small amount of water.

### QUALITY OF QUASSIA.

The quality of quassia may vary and the percentage of quassin which can be extracted from the different grades of chips will not be the same. For this reason the use of quassia chips is not so certain in its results as a material containing a known amount of insecticide. When the quassia chips are used, it is well to look over sprayed areas three days after they are sprayed to be sure that the spray has been effective.

### QUASSIA EFFECTIVE ONLY BY CONTACT.

There is an erroneous impression among some growers that the quassia spray after it has dried upon the leaves will kill the aphides which later appear upon them. The quassia, as well as the other sprays used for the hop aphis, is effective only when in actual contact with the insects.

### EFFECT OF SPRAY MATERIALS UPON THE QUALITY OF SPRAYED HOPS.

It was suggested by some growers that nicotine sulphate, whale-oil soap, and quassia extract might injure the quality of the hops on which they were applied. In order to test this point some nearly ripe hops were sprayed with the following materials, and when the crop was being picked these sprayed hops were picked, dried in the kiln with the other hops, and later sent to Washington for analysis:

Nicotine sulphate, 1–1,000; whale-oil soap, 4 pounds to 100 gallons.
Nicotine sulphate, 1–2,000; whale-oil soap, 8 pounds to 150 gallons.
Nicotine sulphate, 1–3,000; whale-oil soap, 4 pounds to 100 gallons.
Blackleaf tobacco extract, 1–60 and 1–75, each with 2 pounds of whale-oil soap to 100 gallons.
Quassia chips, 7½ pounds; whale-oil soap, 9 pounds to 250 gallons.

The following analyses were received from the Bureau of Chemistry:

TABLE VIII.—*Analyses of hops sprayed with various insecticides.*

| No. | Whale-oil soap. | Nicotine. |
|---|---|---|
| 1 | None. | None. |
| 2 | None. | None. |
| 3 | None. | None. |
| 4 | None. | None. |
| 5 | None. | None. |
| 6 | None. | None. |

The quassia was not tested for, as there is no test that is applicable.

From the above analyses it is evident that the nicotine or whale-oil soap that remained upon the hop cones was not present in sufficient quantities to be detected by a chemical analysis, and therefore would not injure the quality of the hops.

The flour paste is composed of starch and gluten, which has no distinct flavor or odor, and even through it were present in large amounts it can not be conceived how this material could influence the quality of the hops.

### DIRECTION IN WHICH TO WORK.

Since the winged aphides travel largely with the wind, the best results will be obtained, especially where the winds are prevailingly from one direction, by working with the wind. If this is done the

winged aphides will not be able to migrate to the sprayed hops so readily as if the wind were blowing from the unsprayed hopvines to those which have been sprayed.

### CONTROL ON PRUNE.

The hop aphis apparently is capable of migrating some distance, provided the wind is right, and in prune-growing sections it is impossible to kill all of the migratory insects. Where there are only a few prune or plum trees in the neighborhood, however, the destruction of any nonproductive trees and any wild plums that may be present will reduce the number of trees that will have to be sprayed.

The spraying of the plums and prunes can not be relied upon for the control of the hop aphis, but where it is thoroughly and systematically done the severity of the season's infestation may be greatly lessened. Work along this line is strongly recommended.

### FIELD OBSERVATIONS.

About the time that the aphides are expected to appear upon the plum or hop it is advisable to go through the prune orchards or hopyards and note the conditions. Careful observations, if maintained throughout the season, will keep the grower informed as to the severity of the infestation in all parts of his hopyards. He will then be able to check the infestation before any serious damage has been done.

### SPRAYING REPORT.

The following form of a daily report was successfully used by Mr. H. N. Ord at Independence, Oreg., in 1912, to keep a record of the spraying operations in the field:

| Date. | No. acres infested. | No. acres sprayed. | No. gallons used. | Formula and cost per 100 gallons. | Effectiveness of spray applied three days before. | No. machines used. | No. acres sprayed per machine. | Cost of operations per acre. |
|---|---|---|---|---|---|---|---|---|
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
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| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |

If such a report is faithfully kept the grower will always know the condition of his hopyard and what his spraying operations are costing him.

### SPRAYING MACHINERY.

Several forms of outfits may be successfully employed in the hopyards provided that they meet the following requirements: The machine should have a tank capacity of from 75 to 200 gallons,

should supply at least two lines of hose at 120 to 150 pounds pressure, and should be in such order that there will be few breakdowns or delays. Good work can be done with the hand pumps (see Pl. VII, fig. 1), the gasoline power outfits (Pl. VIII, figs. 1, 2), the compressed-air sprayers, etc., provided they meet these requirements and are supplemented by an efficient mixing and supply system.

The knapsack spraying machine (Pl. VII, fig. 2) may, under some circumstances, be of value for work on a very small scale, but is not at all practical in a commercial hopyard.

### BOILING AND MIXING PLANT.

In designing a boiling and mixing plant for work on a large scale it is very desirable to arrange the tanks so that their filling and emptying is accomplished by gravity.

The uppermost tanks should be used for steeping the materials and should be supplied with water from a hydrant; the lower ones should be filled by drawing from the upper ones, or, when diluting is necessary, from a hydrant. The lower tanks, however, should be high enough to drain into a supply wagon.

#### DESCRIPTION OF TANKS.

The boiling and mixing tanks at Independence, Oreg., were made of No. 18 galvanized iron, riveted and soldered together, a ¾-inch iron pipe forming a brace for the tops. Three braces of ½-inch angle iron, placed 3 feet 4 inches apart and riveted to the sides of the tanks, together with a framework of 2 by 4 planks, prevented the tanks from bulging.

#### ARRANGEMENT OF TANKS.

The arrangement of tanks shown in Plate VI, figure 2, was found very satisfactory. Two boiling tanks 10 by 3 by 3 feet 9 inches, heated by steam, were placed upon a 10 by 12 platform, elevated 10 feet from the ground. Passageways were left between and around the tanks. On a near-by but lower platform were three 375-gallon tanks for mixing and storage. A swinging outlet pipe drained the boiling tanks and directed the materials into any one of the three tanks. From the lower tanks the material was run through a long hose into the supply wagons. In order thoroughly to strain the materials the entrances of all the outlet pipes were screened with wire gauze and the ends of the hose were covered with cheesecloth.

### FIELD OPERATIONS.

#### SUPPLY WAGONS.

When extensive spraying operations are being carried on it is essential to have an adequate supply system. In an emergency a farm wagon containing barrels of spray (Pl. VIII, fig. 2) can be used,

FIG. 1.—HAND PUMP AND BARREL ON SLEDGE. (ORIGINAL.)

FIG. 2.—KNAPSACK SPRAYING MACHINE IN USE IN HOPYARD. (ORIGINAL.)

SPRAYING AGAINST THE HOP APHIS.

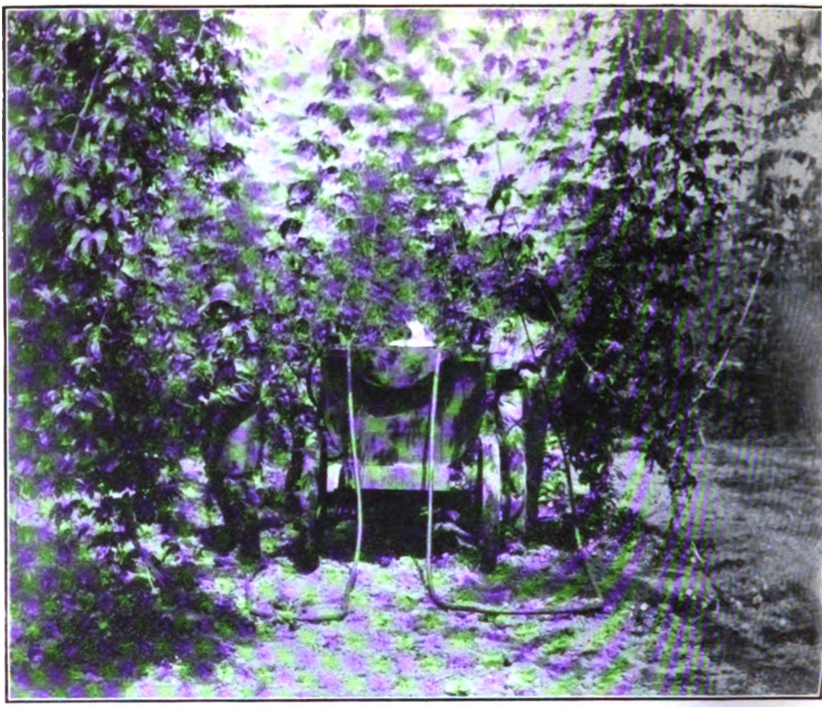

FIG. 1.—POWER OUTFIT ON NARROW TRUCK, IN USE IN HOPYARD. (ORIGINAL.)

FIG. 2.—FILLING POWER OUTFIT FROM IMPROVISED SUPPLY WAGON. (ORIGINAL.)

SPRAYING AGAINST THE HOP APHIS.

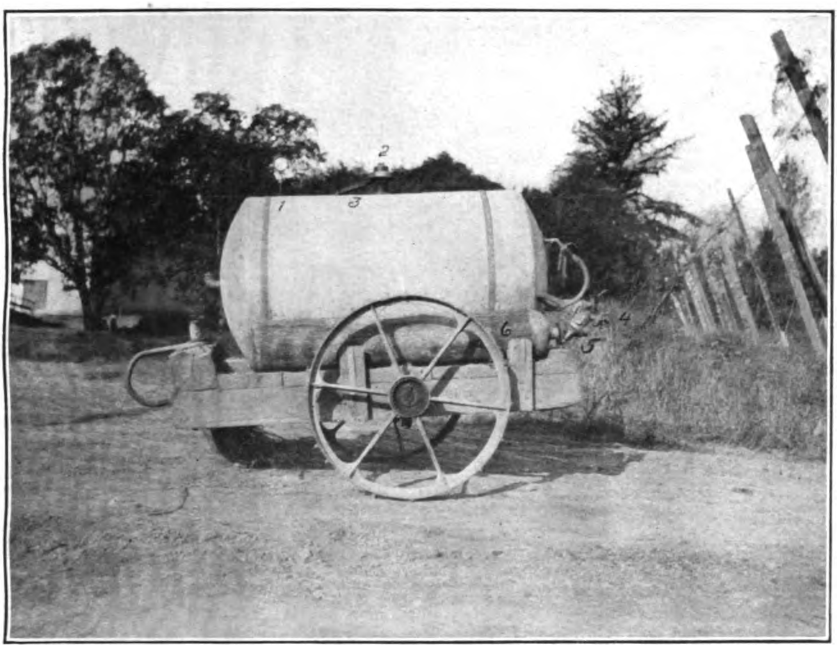

FIG. 1.—COMPRESSED-AIR SPRAYING MACHINE, SHOWING AIR BOTTLE, TANK, REDUCING VALVE, AND PRESSURE GAUGE. (ORIGINAL.)

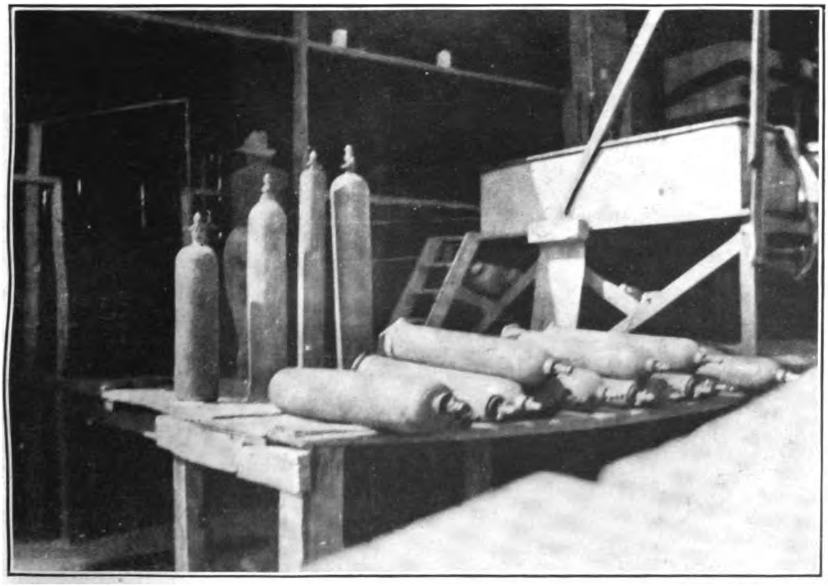

FIG. 2.—FILLING AIR BOTTLES FOR COMPRESSED-AIR SPRAYING MACHINE. (ORIGINAL.)

SPRAYING AGAINST THE HOP APHIS.

but it is very desirable to have a large tank wagon made expressly for this purpose. When low spray tanks are used the spray can be run from the supply tank by gravity, but in most cases it is necessary to employ a good pump.

### EXCHANGE TANKS.

When conducting spraying operations it is desirable to keep the entire force constantly employed. The use of an exchange tank is one of the best methods for accomplishing this purpose. An extra machine is filled after the other machines have started and is exchanged for the first one emptied. The exchange tank is driven down the row in which the nearly empty tank is working. When empty the men move back and take the exchange tank, the empty tank being then refilled and exchanged for the next empty tank.

### SPRAY RODS.

When the hops are growing upon short poles the spray is most readily applied with a short spray rod. In the trellised yards, however, the hops are much taller and a 10-foot rod is necessary. The aphides are mostly upon the underside of the leaves, and in order to wash them thoroughly the spray must be directed from below. When angle nozzles are not available the spray rod may be bent so that the spray is readily directed to the underside of the leaves. If one or the other of these methods is not employed the material will not be satisfactorily applied.

### NOZZLES.

By exercising great care it was found possible to spray the hop-vines thoroughly with a nozzle that produced a very fine mist spray. It was found much easier, however, to do the same work with a nozzle that produced a slightly coarser washing or driving spray. This type of spray is more satisfactory because by its driving force it turns the foliage and dashes over it. When cheap labor is employed good work is more readily obtained with the coarse driving spray than with the very fine mist spray.

### THE COMPRESSED-AIR SPRAYING MACHINE.

The compressed-air spraying machine (Pl. IX, fig. 1), which is described below, was invented by Mr. Theodor Eder, of Perkins, Cal., who by the following statement has generously dedicated it to the use of the public.[1]

Whereas, I, THEODOR EDER, of the town of Perkins, county of Sacramento, and State of California, having invented certain improvements in spraying devices for

[1] A copy of this patent (No. 1046572) may be obtained for 5 cents by addressing the Commissioner of Patents, Washington, D. C.

which I filed on the 20th day of March, 1909, an application for patent of the United States, serial No. 484784; and

Whereas, it is my desire that the public generally shall have the right to use said invention,

Now, therefore, I, the said Theodor Eder, hereby dedicate, grant and convey to the public at large and to whomsoever may desire to use said invention, the full right, liberty and license to make, use and sell apparatus embodying the said invention for the full end of the term of any letters patent which may be granted on said application.

And I hereby authorize and request the Commissioner of Patents to issue any letters patent which may be granted on said application to the people of the United States and Territories thereof as the assignee of my entire right, title, and interests in and to the same.

In witness whereof, I have hereunto set my hand and seal this 31st day of October, A. D. 1912.

THEO. EDER.

This spraying machine (Pl. IX, fig. 1) is composed of a large iron tank, fitted with a pressure gauge (*1*), an inlet pipe with a strong screw cap (*2*) which is opened with a large wrench (*3*), an outlet pipe with cut-off (*4*) and connected through a pressure-reducing valve (*5*) with a large air bottle (*6*). (A large carbonic-acid gas bottle serves this purpose, the larger the better.) This machine is fastened onto a truck made from two old mower wheels and an iron shoe.

Provided that the spray material is thoroughly screened so that no dirt gets in to clog the nozzles, this machine is effective and is so small and light that it is readily hauled through a hopyard by one horse.

The air bottles are filled with air compressed by the air compress to 1,000 or 1,200 pounds (Pl. IX, fig. 2), loaded onto the supply wagon, and hauled with the spray to the field. The spray tank is filled, an air bottle connected with the reducing valve which has been set for 120 or more pounds pressure, the air is turned on, the pressure gauge indicates the pressure that is maintained, and the machine is ready for work.

The following information was received from Mr. Eder and gives data from which the cost of such a machine may be estimated:

Replying to your request in this regard, we beg to advise that the cost of these rigs depends upon the size of the spray tank, etc. A 150-gallon tank in black iron would cost about $42. The reducing valves which we use between the air bottles and the tank cost $10, including pressure gauges and fittings. Mowing machine wheels we buy old, costing from $1 to $1.50 per pair. The axles and other iron work on the truck cost in the neighborhood of $8, and the woodwork, etc., would probably bring the entire truck construction up to $15. The only things you would now have to add are spray hose, pipe, and nozzles, which expense would, of course, vary according to the number of leads and the length of same. We usually use four leads, two of 16 feet and two of 25 feet. We use seven-ply ½-inch hose, costing about 12 cents per foot, and use 10 feet of ¼-inch pipe for spray rod to each lead, and a hop nozzle, which costs approximately 90 cents. The value of the pipe and valve would probably be $1. The air bottles, if purchased in lots, cost $12; singly, probably $15.

For further information we beg to advise that a crew of four spray hands will empty a 250-gallon spray tank on hops about five to six times a day, and this would require

one full air bottle to each tank of spray. However, the same bottles are charged several times in a day, and on some ranches we run 10 or 12 spray rigs with three dozen bottles, and could probably get along with a few bottles less, if necessary.

The air compressor we use is a 10 by 12 double-acting mine compressor with the valves removed from one end. The piston rod is continued on through and the initial compressor puts the air through pipes immersed in water that cool same, and the ram at the other end of the piston rod puts this air up to 1,000 pounds. We use XX ¾-inch steel pipe for leads, and usually fill three or four bottles at a time, or new bottles can be put on and others taken off, without stopping the compressor. The compressor we have designed will charge about 25 bottles per hour, if necessary, all from 1,000 to 1,200 pounds. Lately we are charging quite a lot at 1,200 pounds, especially where we use 250-gallon tanks. Cost of compressor, as fitted, $550.

For small growers it would seem to us that they could club together and buy a compressor and bring their empty air bottles in for recharging, as a bottle gets away with a lot of spray even at high pressure. The reducing valves are so constructed that any pressure desired is obtained. We have also tried the use of carbonic-acid gas for spraying, but we use the spray material up so fast that the gas freezes itself up in the valve while coming out of the bottle when the pressure is being reduced. This could be overcome by the use of an alcohol lamp in the lead line, but this is too cumbersome; besides, air costs less.

E. CLEMENS HORST CO.,
By THEO. EDER.

## COST OF SPRAYING.

The following estimate of the cost of spraying for the hop aphis is made from data taken from actual field work on high-trellis yards. The amount of material needed for hops on short poles will be somewhat less.

It has been found that one machine will spray from 2 to 3 acres per day, and that in order to do thorough work it is necessary to apply from 300 to 500 gallons per acre according to the amount of foliage on the vines. The following data are based upon a machine which will spray 2 acres per day:

Materials: Nicotine sulphate, 1–2,000; flour paste, 4–100. Cost, 70.8 cents per 100 gallons.

| | 300 galls. | 500 galls. |
|---|---|---|
| Applying per acre | $2.13 | $3.54 |
| Labor, 3 men, $2 per day for ½ day | 3.00 | 3.00 |
| 1 horse, 50 cents per day for ½ day | .25 | .25 |
| Total cost per acre of 1 application | 5.38 | 6.79 |

QUASSIA AND WHALE-OIL SOAP.—FORMULA NO. 2.

| | |
|---|---|
| Cost of materials per 100 gallons | $0.69 |
| Cost of cooking | .11 |
| Total | .80 |

| | 300 galls. | 500 galls. |
|---|---|---|
| Applying per acre | $2.40 | $4.00 |
| Labor, 3 men, $2 per day for ½ day | 3.00 | 3.00 |
| 1 horse, 50 cents per day for ½ day | .25 | .25 |
| Total cost of 1 application | 5.65 | 7.25 |

The cost of stripping the vines preliminary to spraying will be from \$1.80 to \$2 per acre.

The cost of spraying for the hop aphis, although apparently great, is nothing compared to the losses which result from neglect to spray for this insect.

Thorough spraying is, then, a good business policy and should be carefully done by all commercial hop growers.

## CULTURAL METHODS.

### CLEAN CULTURE.

Suckers growing between the rows and vines growing over fences and near-by trees usually have much dense foliage, due to the growth

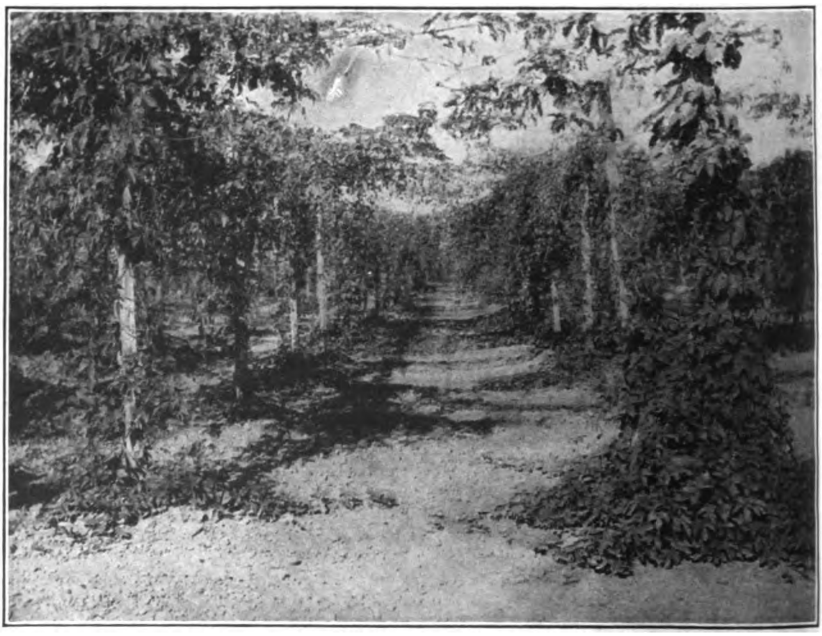

FIG. 8.—Short-pole hopyard, showing dense foliage around base of vines, which harbors the hop aphis. (Original.)

of several plants upon a limited area, and form an ideal breeding place for the aphides. Such plants may form a constant source of infestation and should be promptly removed.

### STRIPPING THE VINES.

One of the most important cultural methods now in use is stripping the vines to a point about 4 feet above the ground (fig. 8). This removes the suckers and dense foliage, which protect and foster the aphides, from around the base of the vines. Experiments show that

FIG. 1.—HOPVINE STRIPPED, AND TIED BELOW THE POINT OF STRIPPING, SHOWING FREE CONDITION OF ALL FOLIAGE.

[This vine may be successfully sprayed.] (Original.)

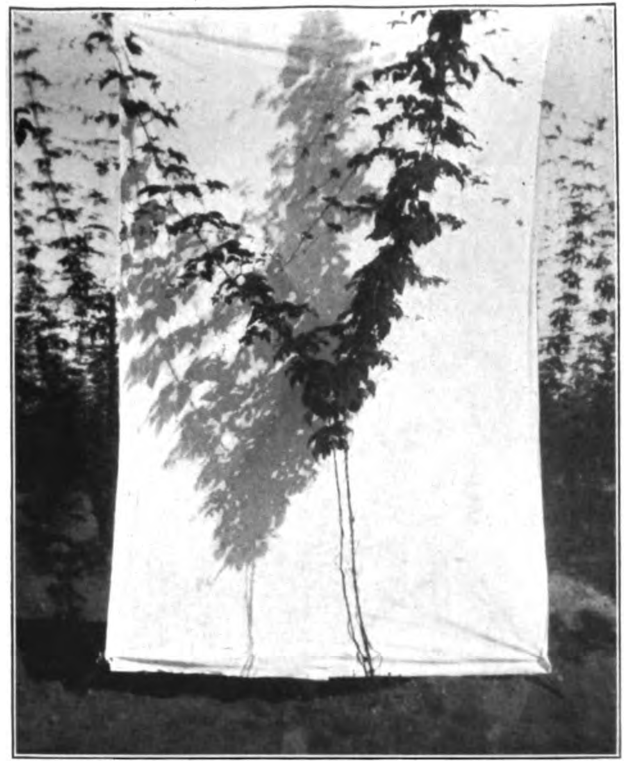

FIG. 2.—HOPVINE STRIPPED, AND TIED ABOVE POINT OF STRIPPING, SHOWING MATTED CONDITION OF LOWER FOLIAGE.

[These vines may not be successfully sprayed.] (Original.)

SPRAYING AGAINST THE HOP APHIS.

when the vines are stripped and tied together above the point of stripping (Pl. X, fig. 2) the foliage below this point is matted and difficult to spray thoroughly, but that when the vines are tied below the first foliage (Pl. X, fig. 1) the leaves are free and the undersides are readily treated. Stripping the vines is a necessary preliminary to the successful control of the hop aphis and should be done before commencing to spray.

#### PICKING OFF INFESTED LEAVES.

It is the custom of some growers to pick off the infested leaves and throw them on the ground. This practice reduces the infestation somewhat, but even though all of the removed aphides die, there are many scattered ones left upon the vines which will soon cause reinfestation. The writer has never observed any good results from this practice alone.

#### FERTILIZATION AND IRRIGATION.

Stimulation of the vines helps them to resist the draining effect of the aphides and encourages the production of the hops, but does not retard the insects in the least, the resulting dense foliage favoring their development. Proper irrigation and fertilization invigorate the hopvines and are very beneficial, but when an infestation occurs they should be supplemented by thorough spraying operations.

### GENERAL SUMMARY, WITH RECOMMENDATIONS.

The investigation of the life history and control of the hop aphis has brought out the following points:

(1) The hop aphis, if not carefully controlled, always injures and may cause a total loss of a large portion of the crop.

(2) The insect may hibernate upon the plum or the hop. The destruction of the hibernating forms will aid in the control of this insect.

(3) The insect is readily killed by several contact insecticides.

(4) Several applications may be necessary to control an infestation successfully.

(5) If successful control is desired the spraying operations *must not be delayed* and the work must be very thorough; all of the leaves of the vines must be wetted on both sides. It is more economical to waste a little material than not to apply enough.

(6) Severe infestations have been successfully checked and clean hops obtained where the spraying operations were thorough.

## THE MORE IMPORTANT WRITINGS ON THE HOP APHIS.


1904. CLARKE, W. T.—Bul. 160, Univ. Cal. Agr. Exp. Sta., 13 pp., 7 figs.

1897. CORDLEY, A. B.—Bul. 45, Oreg. Agr. Exp. Sta., pp. 99, 127, 13 figs., June.
Habits and remedies.

1903. FELT, E. P.—Proc. 24th Ann. Meet. Soc. Prom. Agr. Sci., pp. 39–48.

1865. FITCH, A.—The Country Gentleman, vol. 25, p. 274, April 27.
Destructiveness, enemies, and remedies.

1904. FLETCHER, J.—Bul. 46, Div. Ent., U. S. Dept. Agr., pp. 82–88, May.

1904. FLETCHER, J.—Rept. Exp. Farms Canada, pp. 163–215.

1887. HOWARD, L. O.—Country Gentleman, vol. 52, p. 875, November 17.
First published full life history.

1897. HOWARD, L. O.—Bul. 7, n. s., Div. Ent., U. S. Dept. Agr., pp. 84–87.

1899. HOWARD, L. O.—Hop Industry, Orange Judd Co., New York, pp. 113–141, 19 figs.
Accounts of the species known to affect hops.

1893. KOEBELE, A.—Insect Life, vol. 6, pp. 12–17, November.
Experiments with hop louse in Oregon and Washington.

1887. LINTNER, J. A.—Cultivator and Country Gentleman, vol. 52, p. 511, June 30.
Remedies.

1889. LINTNER, J. A.—New England Homestead, p. 253, July 27.
Remedies for hop aphis.

1891. LINTNER, J. A.—New England Homestead, p. 193, May 2.
How to control the hop aphis.

1900. LUGGER, O.—Bul. 69, Minn. Agr. Exp. Sta., pp. 250, 200 figs., 16 pls.

1904. PETTIT, R. H.—Spec. Bul. 24, Mich. Agr. Exp. Sta., pp. 79, 70 figs.

1908. REMISCH, FR.—Zeitschrift für wissenshaftliche Insektenbiologie, vol. 4, no. 10, pp. 365–366.
Important enemy of hops.

1910. REMISCH, FR.—Zeitschrift für wissenshaftliche Insektenbiologie, vol. 6, no. 6, p. 242.
Mentioned in article on *Adalia bipunctata* as the principal food of that species.

1911. REMISCH, FR.—Zeitschrift für wissenschaftliche Insektenbiologie, vol. 7, nos. 7–8, pp. 240–243; no. 9, pp. 282–285.
Article, "The hop leaf louse, *Aphis humuli*."

1891. RILEY, C. V.—Cir. 2, 2d ser., Div. Ent., U. S. Dept. Agr., pp. 7, 5 figs., 1 pl., June.

1891. RILEY, C. V.—Insect Life, vol. 3, pp. 181–210, January.

1893. RILEY, C. V.—Ann. Rept. U. S. Dept. Agr., pp. 199–226, 3 pls.

1891. RILEY, C. V., and HOWARD, L. O.—Insect Life, vol. 3, p. 350, April.

1891. RILEY, C. V., and HOWARD, L. O.—Insect Life, vol. 3, p. 486, August.
Hop lice on Pacific Coast.

1891. RILEY, C. V., and HOWARD, L. O.—Insect Life, vol. 4, p. 84, October.
Quassia for the hop aphis.

1892. RILEY, C. V., and HOWARD, L. O.—Insect Life, vol. 4, pp. 342–343, June.
Hop louse in the extreme northwest.

1892. RILEY, C. V., and HOWARD, L. O.—Insect Life, vol. 4, p. 401, August.
Hop aphis remedies.

1892. RILEY, C. V., and HOWARD, L. O.—Insect Life, vol. 4, p. 406, August.
The hop louse in Oregon.

1892. RILEY, C. V., and HOWARD, L. O.—Insect Life, vol. 5, p. 60, September.
The hop plant-louse in Washington.

1893. RILEY, C. V., and HOWARD, L. O.—Insect Life, vol. 6, p. 53, November.
Hop lice in New York State.

1912. SANDERSON, E. D.—Insect Pests of Farm, Garden, and Orchard, pp. 275–278, figs. 202–204.
On hop.

1891. WASHBURN, F. L.—Bul. 10, Oreg. Agr. Exp. Sta., pp. 23–24, figs. 5.
Description and treatment.

1893. WASHBURN, F. L.—Bul. 25, Oreg. Agr. Exp. Sta., pp. 9–12.
Treatment.

1894. WASHBURN, F. L.—Bul. 31, Oreg. Agr. Exp. Sta., pp. 79–88, 3 figs., 2 pls., April.

1894. WASHBURN, F. L.—Bul. 31, Oreg. Agr. Exp. Sta., p. 82, April.
Brief notes, with suggestions as to remedies.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 112.

L. O. HOWARD, Entomologist and Chief of Bureau.

# PRELIMINARY REPORT ON THE ALFALFA WEEVIL.

BY

F. M. WEBSTER,

*In Charge of Cereal and Forage Insect Investigations.*

ISSUED MAY 14, 1912.

WASHINGTON:
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1912.

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### CEREAL AND FORAGE INSECT INVESTIGATIONS.

F. M. WEBSTER, *in charge.*

GEO. I. REEVES, W. J. PHILLIPS, C. N. AINSLIE, E. O. G. KELLY, T. D. URBAHNS, HARRY S. SMITH, GEO. G. AINSLIE, J. A. HYSLOP, W. R. WALTON, J. T. MONELL, J. J. DAVIS, T. H. PARKS, R. A. VICKERY, V. L. WILDERMUTH, E. G. SMYTH, HERBERT T. OSBORN, PHILIP LUGINBILL, C. W. CREEL, E. J. VOSLER, R. N. WILSON, VERNON KING, *entomological assistants.*
NETTIE S. KLOPFER, ELLEN DASHIELL, *preparators.*
MIRIAM WELLES REEVES, *collaborator.*

# LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
*Washington, D. C., January 2, 1912.*

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 112 of this bureau, the manuscript of a preliminary report on the investigation of the alfalfa weevil in Utah and adjacent States. The investigations of the Bureau of Entomology in cooperation with the Utah Agricultural Experiment Station began April 1, 1910, and still continue. The period covered by this report is from April 1, 1910, to November 15, 1911. From April 1, 1910, to April 1, 1911, the bureau was represented in the investigations with but one assistant. Since that time the force has been increased until eight or nine persons have been from time to time employed. The information given is exactly what the title of the bulletin implies, preliminary in nature and not to be taken as conclusive in all cases. It is simply a short account of what has been done within the period of time just indicated.

Respectfully,

L. O. Howard,
*Entomologist and Chief of Bureau.*

Hon. James Wilson,
*Secretary of Agriculture.*

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# PRELIMINARY REPORT ON THE ALFALFA WEEVIL.

## INTRODUCTION.

The alfalfa weevil belongs to a genus or group of beetles all of the members of which attack clover, alfalfa, and closely allied plants. Even before the appearance of this one, *Phytonomus posticus*[1] Gyll. (fig. 1), in our midst several other species had been introduced from Europe, had become established in our fields, and had spread to a greater or less extent over the country.[2] After becoming fully developed in early summer, all apparently have the same habit of scattering themselves over the country, a little later crawling into any secluded place that they can find, there to pass the winter. Years ago a lady residing in Michigan and spending the summer in New York, where one species of these beetles, *Hypera punctata* (fig. 2), was at the time very abundant, on her return home and on unpacking her trunk found some of them ensconced among the contents. They had in all probability secreted themselves, either in the trunk itself while it was being packed, or else among articles of clothing exposed out of doors prior to being packed in the trunk.

The alfalfa weevil is found in Europe, western Asia, and northern Africa, where, though it sometimes becomes abundant, it is not especially destructive. The foregoing will illustrate the numerous ways whereby it might have been introduced into this country in articles of commerce, in household goods, or among other belongings of immigrants coming from those countries.

## FIRST APPEARANCE OF THE ALFALFA WEEVIL IN THE UNITED STATES.

The pest was first reported on the outskirts of Salt Lake City, Utah, in the spring of 1904. At that time it had seriously injured several acres of alfalfa, the first crop being damaged fully one-half and the second crop practically destroyed. The following spring, 1905, its work was observed several miles way. The particular locality where the pest was first observed is on the eastern border of the city. Although not far distant from nurseries, it is not in close

[1] In a recent paper, "The Genera Hypera and Phytonomus in North America north of Mexico" (Annals of the Entomological Society of America, vol. 4, no. 4, pp. 383, 473, pls. 24–34, December, 1911), Prof. E. G. Titus has given this species as *P. posticus* Gyll. *Phytonomus punctatus* had already been placed in the genus *Hypera* by European authors.

[2] *Phytonomus punctatus* Fab.: See Report of the Commissioner of Agriculture for 1881–82, pp. 171–179; *Phytonomus nigrirostris* Fab.: See Bul. 85, Part I, Bur. Ent., U. S. Dept. Agr., 1909. For other species of the genus see paper by R. L. Webster, Ent. News, vol. 20, pp. 80–82, 1909.

proximity to any railway; it is, on the other hand, among the habitations of the more humble class of people, such as have come from foreign countries. The correct inference, therefore, would seem to be that it was introduced with nursery stock or in the household effects of immigrants. The pest had gained a foothold, doubtless, years earlier, but had increased from perhaps a single pair and was too few in numbers to attract attention up to the time when it had become destructive over several acres and when it had probably spread in limited numbers far beyond. In the immediate vicinity of this seriously infested field, and indeed throughout the country about Salt Lake, alfalfa long ago escaped from cultivation and now grows as a weed generally on vacant lots (Pl. I, fig. 1) and other uncultivated areas like roadsides and railroad rights of way (Pl. I, fig. 2), so that it would now be impossible to determine, even approximately, the exact time and location of the original landing of the first individuals in Utah. As a matter of fact the insect might easily have been brought into the country again and again and have perished because the locality in which it ended its voyage was destitute of growing alfalfa.

FIG. 1.—The alfalfa weevil (*Phytonomus posticus*): Adult. Much enlarged. (Author's illustration.)

## SPREAD OF THE PEST.

From the single infested alfalfa field near Salt Lake, the only one known up to the year 1904, the pest evidently became somewhat widely diffused and by the following year was found several miles distant to the southeast. It was not, however, until 1907 that it was brought to the attention of the Utah Experiment Station and not until 1908 that attention was called to the matter in print by Prof. E. G. Titus,[1] entomologist of the Agricultural College and Experiment Station, although by the fall of 1907 it had spread over all of the alfalfa-growing section lying immediately east of Salt Lake and Murray.[2] By July 1, 1910, the infested area covered the greater part of Salt Lake and contiguous portions of adjoining counties, aggregating an area approximately 60 by 70 miles in extent.[3]

Up to September, 1911, the insect had extended its area of diffusion directly northward as far as Tremonton, east to Evanston, Almy, and Lyman, Wyo., and northeast to Cokeville, Wyo., Randolph and Laketown, Utah, and Fish Haven, Idaho.

[1] Deseret Farmer, Salt Lake City, Utah, September 26 and October 3, 1908.

[2] Bul. 110, Utah Agr. Coll. Exp. Sta. The Alfalfa Leaf-Weevil, by E. G. Titus, Logan, Utah, September, 1910.

[3] Loc. cit., map 1.

INVESTIGATIONS BY THE UTAH EXPERIMENT STATION.

From the time the attention of the Agricultural Experiment Station authorities at Logan, Utah, was called to the pest and its destructive proclivities they began to investigate and experiment with a view of overcoming its ravages. Following the breeding season of 1909, however, the situation became so alarming as to make it clear that the State of Utah could not hope to cope with the pest single-handed. Besides, there was no longer a doubt that it would soon spread to alfalfa fields in other States, thus becoming a matter of interstate concern.

On August 4, 1909, his excellency William Spry, governor of Utah, appealed to the honorable the Secretary of Agriculture for assistance in controlling the insect and, if possible, preventing its spread into other States.

It was exceedingly unfortunate that this outbreak of the pest was not made known long before in order that it might have been investigated, for at this time it had become too widespread and destructive to be dealt with by any ordinary force of men. Besides, at this time the funds available with which to carry on investigations were wholly inadequate.

The appropriations made for the Bureau of Entomology for the fiscal year 1910–11 gave a slight increase of funds, $2,000 of which provided for cooperation with the State of Utah in investigation of the alfalfa weevil. None of this sum would, however, become available until July 1, 1910, after the season for the investigation of the insect had largely passed for the year. In view of the seriousness of the situation Mr. C. N. Ainslie was sent to Salt Lake, Utah, to take up cooperative work, April 1, 1910, lack of available funds prohibiting any further detail for the purpose.

At this time the entire cooperative force consisted of but two trained men, Mr. Ainslie, of the Bureau of Entomology, and Prof. E. G. Titus, of the Utah Agricultural College and Experiment Station, and Mr. Sadler, a student assistant, also from the experiment station.

From the fact that the experiment station people had carried out a number of field experiments against the weevil and had other experiments in view, and because of the bureau's limited funds for this work, it was deemed best that Mr. Ainslie devote his principal time to a close study of the insect itself and its habits, leaving the field experiments to be carried on by and under direction of the experiment station. The results and information thus obtained up to July 1, 1910, were embodied in Bulletin No. 110 of the Utah Experiment Station, by Mr. Titus, of which the author thereof has given the following synopsis:

The alfalfa leaf-weevil is a small, oval, brown snout-beetle, about $\frac{3}{16}$ of an inch long, that is attacking alfalfa in Utah. It is not a native species but has come to Utah from Europe.

It feeds on plants belonging to the alfalfa family, injuring all parts of the plant above ground.

The eggs are laid in the spring and early summer in the stems or on the buds and leaves, and hatch in about ten days. The young or larvæ are small alfalfa-green worms with a black head; they never become much more than one-quarter of an inch in length when full grown. They feed on and in the leaf-buds, in the stalks and on the leaves.

The larvæ have no true legs and have the habit of feeding or resting in a curled position.

When full grown, about 50 or 60 days after hatching, they go to the ground and spin around them a lace-cocoon, in which, in about fourteen days, they have turned into the full-grown, hard-shelled adult.

This adult feeds on the stems, leaves and buds for several weeks and in August goes into hibernation for the winter, seeking any well sheltered place.

The insect now occurs in Salt Lake, Davis, Weber, Morgan, Summit, Wasatch, Utah, and Tooele Counties, and threatens to eventually reach all our alfalfa growing regions. It spreads rapidly in the adult or beetle stage by flying in spring and summer and by being carried with articles shipped from an infested region, and on railroads, in wagons and automobiles, traveling through the places where it occurs.

It is recommended that alfalfa be disced in early spring to stimulate it to better growth. That the first growth be cut when the most of the eggs have been laid (middle of May), and then brush-drag the field thoroughly.

Sheep may be pastured on the fields at this time for two weeks, and alfalfa then watered and a good crop will usually be assured.

Gathering machines to capture the larvæ and beetles have given good results when used on the fields at the time the insects are most numerous.

Fields should be brush-dragged again after the first crop has been cut.

All weeds and rubbish should be cleaned from fields, yards, ditches and fence rows so that there will be less opportunity for the weevils to find winter shelter.

Alfalfa should not be allowed to grow more than seven or eight years in infested districts.

The amount of work that the Utah Experiment Station did with its limited means and lack of trained men is certainly most commendable, and it is difficult to see wherein the course adopted by the station director (Dr. E. D. Ball) and his subordinates could have been improved upon. It was from the beginning an unequal contest, and the only wonder is that so much good was accomplished with the limited means available.

## COOPERATION OF THE BUREAU OF ENTOMOLOGY AND THE UTAH EXPERIMENT STATION.

There was the same basis of cooperation between the Bureau of Entomology and the Utah Experiment Station from April 1 until September 1, 1910, when Prof. Titus left the State, leaving Mr. Ainslie, and for a few weeks Mr. Sadler, to carry on the work. In the agricultural bill covering the fiscal year from 1911–12, under appropriations for cereal and forage insect investigations, $10,000 of this appropriation was made immediately available on passage of the act, to enable the bureau to take up investigations of the alfalfa weevil promptly in the spring of 1911. With the aid of

FIG. 1.—Volunteer growth of alfalfa on vacant lots in Salt Lake City, Utah. The alfalfa plant beside the hat contained at the time approximately 1,200 to 1,300 eggs. This was in the midst of the egg-laying time. (Original.)

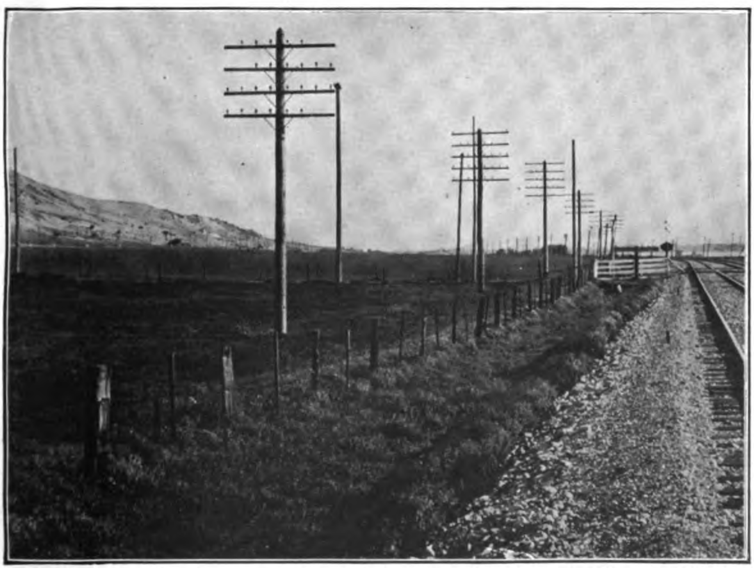


FIG. 2.—Volunteer alfalfa growing along the right of way of the Oregon Short Line Railway a short distance north of Salt Lake City, Utah. (Original.)

CONDITIONS FAVORING THE SPREAD OF THE ALFALFA WEEVIL.

this fund, on April 1 a corps of entomologists was sent to Salt Lake City, Utah, for the purpose of carrying out a thorough study of the insect and its ravages, with special reference to methods of control. Gradually other assistants were detailed, until the number employed in and about Salt Lake was increased to nine, exclusive of the student assistant detailed from the State Agricultural Experiment Station.

The primary object of this work was, so far as possible, to restrict the insect to the area it then occupied and to use every effort, by field experiments in measures of control, to devise means of lessening its destructiveness.

In the meantime it has been learned definitely that the alfalfa weevil was largely held in check in its native home by its natural enemies. Mr. W. F. Fiske, in charge of the Gipsy Moth Parasite Laboratory, having been detailed for work in Italy, kindly volunteered to look into the matter of natural enemies of the weevil and, so far as was possible without interfering with his other duties, to send over to this country any insect enemies that seemed to him susceptible of colonization in Utah. The object of this was to get these insect enemies established, in so far as it was practicable to establish them, at the earliest possible date, in order that they might have the opportunity to diffuse themselves during the spring of 1911. The value of Mr. Fiske's services at this time and in this direction can hardly be overestimated. A more detailed account of this matter will be found under a discussion of the introduction of the natural enemies of the alfalfa weevil.

Very naturally the alfalfa weevil work divided itself into two branches: (1) The field work, which included all mechanical measures for controlling the pest in the field; and (2) the work, necessarily carried out largely in the laboratories at first, involved in the care and management of the parasitic material dispatched by Mr. Fiske from Italy. After the beginning of the fiscal year 1911–12 the experiment station was able to add but slightly to the force of investigators. By this time, however, the annual generation of the weevil had developed to the adult stage and laboratory investigations had largely decreased.

While, as shown, the experiment station, owing to circumstances not under its control, was not able to put into the field men trained for this kind of work, the bureau was able by the aid of the immediately available fund to overcome this difficulty. In the meantime, however, the experiment station did its full share in other directions. Dr. Ball, director of the station, did not hesitate to use his personal and official influence whenever and wherever it could be of service in advancing this work. Besides this, in a great many cases he was able to relieve the bureau of expenses of field investigations as well as to carry a number of other items of expense for which it would

have been impracticable for the bureau to have provided. It may be stated, then, that from April 1 to September 1, 1910, the cooperative work was largely under the direction of Prof. E. G. Titus of the experiment station. From September, 1910, to April, 1911, it was mostly carried on personally by Mr. C. N. Ainslie. During the spring and summer of 1911 the investigation was carried on under the general direction of those connected with the Bureau of Entomology. Outside of the work on parasites, which has been carried on wholly by the bureau, it is not possible distinctly to indicate just what part of the cooperation was carried on by either the bureau or the experiment station. This combination has been for the purpose of accomplishing the greatest amount of good, and there has been no inflexible line separating the work of the two cooperative bodies. As a matter of fact, the results obtained could not have been secured under any other arrangement or with less unselfish feeling than has existed among those engaged in the investigation.

## COOPERATION WITH OTHER BUREAUS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

Observations made by Mr. W. F. Fiske in the vicinity of Naples, Italy, during the spring of 1910 appeared to indicate a possible preference on the part of the alfalfa weevil for certain varieties of alfalfa. Those varieties, notably, having a slender stem appeared to be less freely attacked as compared with those varieties having more robust stems. It was with the view of perhaps being able to find a variety of alfalfa more or less objectionable to the alfalfa weevil that a cooperative experiment was taken up with the Bureau of Plant Industry.

### VARIETY EXPERIMENT.

The Chief of the Bureau of Plant Industry, therefore, detailed Mr. Roland McKee, of the Office of Forage Crop Investigations, to superintend the seeding of a number of varieties of alfalfa (*Medicago sativa*) and the following closely related species: *Medicago falcata* L., *M. ruthenica* (L.) Trautv., *M. lupulina* L., *M. ciliaris* (L.) All., *M. echinus* Lam., *M. hispida nigra* (Willd.) Burnet, *M. hispida confinis* (Koch) Burnet, *M. hispida terebellum* (Willd.) Urban, *M. muricata* (L.) All., *M. orbicularis* (L.) All., and *M. scutellata* (L.) Mill. The tests of these varieties are being conducted on a farm in the vicinity of Salt Lake City, Utah.

Such observations as it has been possible to make upon the young plants involved in this experiment will be found recorded under food plants. It will of course be understood that the most valuable and decisive information bearing upon the relative extent of attack in these different varieties of alfalfa can not be observed until the spring of 1912. Therefore the information now given must be regarded as only initiative.

## INVESTIGATIONS OF VERTEBRATE ENEMIES.

In order to determine what assistance might be expected from birds and other animals besides insects, arrangements were made with the Biological Survey to send an assistant to Salt Lake in order to carry out extended investigations along this line. Mr. E. R. Kalmbach was detailed for this work by the Chief of the Biological Survey and proceeded to Salt Lake, Utah, making continuous observations there from May 7 to July 5, 1911.

It is not possible at the present time to give the results of this work in detail, but a list of the vertebrate enemies observed attacking the alfalfa weevil will be found under the heading Natural Enemies.

## THE INSECT NOT CORRECTLY DETERMINED.

In the bulletin of the Utah Experiment Station, to which reference has already been made, the name of the insect is given as *Phytonomus murinus* Fab., and this name was also applied to the same insect by the writer in Circular No. 137 of the Bureau of Entomology, issued April 20, 1911. It had been so determined by one of the best American authorities on this order of insects. It has, however, proved to be a closely related insect (*Phytonomus posticus* Gyll.), much more common and injurious to alfalfa in Europe, western Asia, and northern Africa, and in these countries known generally as *P. variabilis* Hbst., meaning literally the variable Phytonomus. It is, however, less destructive in the Eastern Hemisphere than it bids fair to be in this country, because of its natural enemies at home, which, as it appears, were not brought over with it when it was first introduced.

## APPEARANCE OF A SECOND SPECIES IN UTAH.

A much larger species, *Hypera punctata* Fab. (fig. 2), the clover-leaf weevil, has recently been found about Malad, Idaho, by Mr. H. T. Osborn, and about Ogden, Utah, by Mr. E. J. Vosler, both of this bureau. This is a larger insect than the alfalfa weevil, but may be confused with it by the ordinary farmer. It had not before been observed between the Rocky Mountains and the Cascades.

While known as a clover insect, this last beetle did some damage to alfalfa in Virginia during June, 1910.

## DESCRIPTION AND SEASONAL HISTORY OF THE ALFALFA WEEVIL.

The fully-developed alfalfa weevil, *Phytonomus posticus* Gyll. (fig. 1), is a small, rather insignificant appearing beetle, slightly under one-fourth of an inch long, of a brown color, mixed with gray and black hairs arranged in indistinct spots and stripes on the back, as shown in figure 1. Rubbed individuals may be very dark, verging on black.

The beetles pass the winter hidden away among matted grass or other similar vegetation, including alfalfa, and, indeed, among most kinds of rubbish anywhere, wherever they will be protected from the weather. The beetles have also been found in early spring under clods and about the crowns of alfalfa plants where the ground had been roughly cultivated the previous autumn. The overgrown margins of fields and irrigation canals and ditches afford excellent places for hibernation, some of which are shown in Plate II, figures 1, 2, and 3.

With the first warm weather in spring the beetles become active and diffuse themselves over the alfalfa fields, feeding upon any living part of the plants that have escaped the winter or, as soon as it commences to push forth, on the fresh growth, both leaf and stem. During some years the beetles are abroad in the fields in Utah early in March; in other and colder springs it may be April before they bestir themselves. Latitude and elevation, with the consequent modifications of temperature, will have much to do in deciding the time of emergence from winter quarters in spring. They also to some extent hibernate in the alfalfa fields.

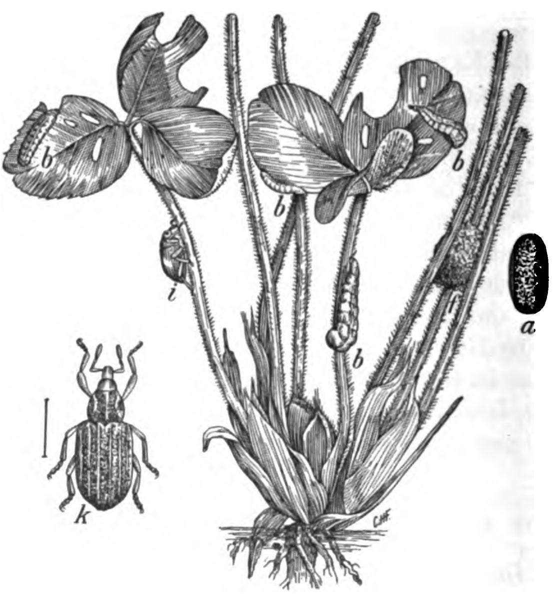


FIG. 2.—The clover-leaf weevil (*Hypera punctata*): *a*, Egg; *b, b, b, b*, larvæ feeding; *f*, cocoon; *i*, beetle; *k*, same, dorsal view. (*b, f, i*, Natural size; *k*, enlarged; *a*, greatly enlarged.) (From Riley.)

As soon as the beetles have spread from their winter quarters out over the fields they pair, and the females are ready to deposit their eggs (figs. 3, 4). As a matter of fact, however, pairing has been observed in the fall, and females taken while hibernating are observed to lay 75 per cent of fertile eggs. According to the notes of Mr. Fiske, made in Italy, they may place their eggs in the old, dead, overwintered stems or even in the dead stems of plants other than those of alfalfa, but in Utah the beetles refused to oviposit in dead stems in the laboratory cages. According to Dr. Giovanni Martelli,[1] at Portici in 1909 the first adults which he obtained appeared toward

[1] First contribution to the biology of *Phytonomus variabilis* Herbst. Bollettino del Laboratoria di Zoologia Generale e Agraria della R. Scuola Superiore d'Agricoltura in Portici, vol. 5, March, 1911.

FIGS. 1 and 2.—Hibernating places of the alfalfa weevil along fences and borders of fields in the vicinity of Salt Lake City, Utah. (Original.)

**FIG. 3.—One of the main irrigation ditches in the Salt Lake Valley, a favorable hibernating place for alfalfa weevils. Photographed July 7, 1911. (Original.)**

HIBERNATION OF THE ALFALFA WEEVIL.

the end of April; at Acicastello in 1910 they appeared during the first part of the second half of April. The maximum birth at Portici in 1909 took place toward the end of the second decade of May and the last adults were hatched near the end of May. At Acicastello the maximum birth took place in the first decade of May and the last were hatched during the second decade of the same month.

The females do not, however, always confine themselves to alfalfa stems in ovipositing. On April 18, 1911, Mr. T. H. Parks found eggs of Phytonomus in punctures similar to those made in alfalfa in the stems of the ground plum, *Astragalus arietinus*. Later Mr. C. N. Ainslie found a number of these eggs in similar punctures, also in the stems of this plant, there being usually six or eight eggs in each puncture. Afterwards Mr. Ainslie found larvæ feeding on *Astragalus utahensis*.

A few days before, Mr. Parks had also found eggs deposited on the surface of leaves, on bits of trash, on the inside of a split stem of grass, and, in one case, upon the bare ground.

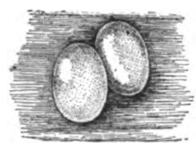


FIG. 3.—The alfalfa weevil: Eggs. Greatly enlarged. (Author's illustration.)

In a very early spring some of the eggs may be deposited outside of the plant, but evidently this is not usual and occurs mostly when the growing stems of alfalfa are too small or not sufficiently numerous to satisfy the requirements of the females in this direction. In preparing for egg deposition the female punctures the stem with her beak. The punctured stems and a group of these eggs in place are shown in figure 4.

The method of oviposition has been described by Mr. Titus.[1]

Observations were made by Mr. C. N. Ainslie in which he found that oviposition seemed to be accomplished by forcing the beak into the fleshy tissues of the stem, sometimes into a hollow stem, in which case the eggs are merely placed in the natural cavity. Where placed in a leaf petiole, as is sometimes the case, the cavity for the eggs must be necessarily eaten out. Generally in these eaten cavities only 4 or 5 eggs are placed, while in the hollow stems 15 or 20 seem not uncommon. Once or twice Mr. Ainslie found eggs placed below the enlarged base of the petiole. In this case the eggs were placed in position through a hole made through the base of the petiole and the mass of eggs was well protected by the hairy leaf buds and unfolded leaflets behind the base of the petiole. Once in a while the hole into the stem is eaten and the beak not merely forced in, in which case the gleam of the yellow eggs can be seen through the tunnel into the stem. When the opening is forced it is left more or less filled with fibers that have been disrupted or forced aside by the beak and the ovipositor. These fibers are often blackened from

[1] Bulletin 110, Utah Agr. Coll. Exp. Sta., pp. 38–39, September, 1910.

some cause, perhaps simple oxidation, and appear quite different from the "feeding holes" that are much more common. These latter are either saucer or cup shaped cavities eaten into the plant stem or punctures through the epidermis that are enlarged inside the stem.

In one alfalfa stem Mr. Ainslie found 4 egg "nests," the holes being in pairs. These pairs were one-half to three-fourths of an inch between the separate holes, and each pair was in a separate node, the pairs perhaps 3 inches distant from each other. There must have been 30 or 40 eggs at least in this one stalk. It was picked from a vigorous crown growing beside a manure pile, and nearly every other stem in this crown contained eggs. These shoots were tall and had evidently grown rapidly. Indeed this seems to be the kind of stem chosen by this insect in which to place the eggs; shorter, woodier stems seem seldom to be selected for this purpose

FIG. 4.—The alfalfa weevil: Larvæ attacking a sprig of alfalfa, and eggs, *in situ;* larva, enlarged, at right. (Author's illustration.)

As observed by Messrs. Wilson and Parks, assistants of the bureau, the female beetle, after excavating the cavity for the eggs, inserted her ovipositor and laid a number of eggs before removing the ovipositor from the cavity. After this she began beating it up and down rapidly over the puncture as though pounding the orifice, sometimes but not always excreting a drop of watery material over the puncture. This secretion when hardened appeared to seal the opening. In some cases the arrangement of the eggs in rows on each side of the puncture, as described by Mr. Ainslie, was verified.

Mr. Titus has described the egg [1] as being oval, rounded at the ends, and when first deposited lemon-yellow in color. As the eggs incubate they become darker at one end and a deeper yellow in the other

[1] Bulletin 110, Utah Agr. Coll. Exp. Sta., p. 34, September, 1910.

portions. Under the microscope the surface of the egg is very slightly roughened and sculptured.

Mr. Ainslie, who made a careful study of the egg (fig. 3) at oviposition and later, found that at time of laying the egg was a mere sac, the shell being little more than a transparent, homogeneous envelope or membrane. As segmentation proceeded this membrane became very faintly pitted, and under the microscope with proper illumination barely discernible reticulations, both pentagonal and hexagonal, were apparent. Both ends and sides seemed equally reticulated, the areolation being perhaps a little smaller at the ends. After the larva emerges the shell that remains is a transparent structureless membrane with no trace of reticulation.

The number of eggs placed in a cavity varies greatly, there sometimes being not more than 2 or 3, ranging up to over 30; probably 10 would be about the average number, although these figures are of course only approximate. Mr. Parks found that during the first half of April the number ranged from 3 to 18, averaging 7 or 8; during the last half and early May the number increased, 25 or 30 being the maximum, with an average of 8 or 9. With reference to the number of eggs that may be deposited in a single alfalfa plant, the one shown beside the hat in Plate I, figure 1, examined on April 23—at which date oviposition was still in progress and the beetles preparing for oviposition were still exceedingly numerous in the fields—indicated that this plant at this date contained nearly if not quite 1,300 eggs. Of course, in fields where the alfalfa grew up thickly there would be a relatively less number per plant, but these figures serve to illustrate the origin of the countless myriads of larvæ that swarm over the plants in an alfalfa field and render more easy of comprehension the destruction shown in Plate III, figure 1. The difference between uninjured and affected plants is shown in Plate III, figure 2, *a* and *b*. Other ravaged fields are shown in Plate IV, figures 1 and 2, in contrast with figure 3 of same plate.

In the Salt Lake Valley oviposition has been found to take place earlier on the bench lands than lower down in the valley itself.

### Egg-Laying Period.

The period of egg laying is a matter of considerable significance, since in some degree it will decide the question of efficiency or practical measures of control. As is usual with insects, after a female has exhausted her supply of eggs she dies and there is no second depositing of eggs by her during that season. The actual time required for the individual female to deposit her supply of eggs is of course influenced by the weather. In 1909 egg laying began in the fields early in April, and eggs were found in greatest abundance during the last of May and the first of June. In 1910 egg laying began early

in March and was at its height by the middle of May, and Mr. C. N. Ainslie found eggs in a rearing cage where beetles were confined indoors as late as October 22, and others found them as late as November 10, and Mr. E. J. Vosler on December 6, while larvæ of all sizes were found rarely in the fields November 1. On this latter date the sexes were pairing in the fields and some of the females contained apparently mature eggs, but none could be found deposited in the fields. In 1911 Mr. Urbahns found eggs and very young larvæ March 31, and adults active in the field on a warm day (January 31, 1912); one feeding and one pair mating.

The time required for the eggs to hatch after being deposited is, according to Mr. Titus, from 7 to 16 days, as observed by Mr. Ainslie about 10 days, and according to Mr. Parks's observations about 13 days. The three series of observations were made during different years, 1909, 1910, and 1911, and, of course, under different temperature conditions. It would seem as though more or less pairing is done in very late fall and the eggs deposited the following spring. Of course, the scattering eggs and larvæ found throughout the late summer and fall have little economic importance except to indicate what might be expected in more southern localities, although even in Utah some eggs probably survive the winter.

## Evidence of a Partial Second Generation.

The occurrence of larvæ up to the approach of cold weather in late fall has already been noted. Some of these at least might be accounted for from the fact that overwintering females still containing eggs are found throughout July and early August; but that others of these larvæ are the offspring of parents developing during the preceding spring is strongly indicated by the fact that the females depositing eggs from which larvæ afterwards hatch are in perfect condition, unrubbed, and apparently fresh.

Under date of October 19, 1910, Mr. Ainslie found that eggs were being deposited in his rearing cages, dropped at random on stems and leaves and even on the sides of the cage, but in no case did he observe them placed within the stem. There were in this cage 150 adults, some of which were undeniably trim and fresh as though they had just emerged, while others were pretty well worn, and there were all intervening gradations. Adult females swept from alfalfa November 2 were found to have oviposited two days later. Adults taken from the fields November 7 and kept indoors were found to have deposited eggs within 2 or 3 days prior to November 30.

During the season of 1911 it was possible still further to substantiate the foregoing by an extensive series of observations carried on by several of those engaged in the investigation, and besides to add even more evidence that some of these late-appearing larvæ are the

FIG. 1.—One of the worst infested fields in the Salt Lake Valley, showing injury to the first crop of alfalfa, which was left uncut. Photographed June 26, 1911. (Original.)

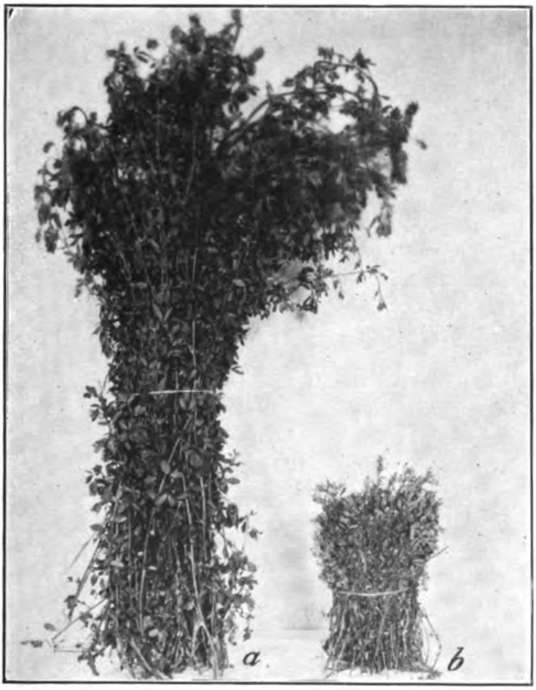



FIG. 2.—a, Bunch of alfalfa uninjured by the alfalfa weevil. b, Bunch of alfalfa badly injured by the alfalfa weevil, showing growth made by first crop in the badly infested fields. Photographed June 20, 1911. (Original.)

INJURY WROUGHT BY THE ALFALFA WEEVIL.

FIG. 1.—Crop secured from first cutting of one of the worst infested fields. Photographed June 9, 1911. (Original.)

FIG. 2.—First cutting from another field damaged from attack by the alfalfa weevil. Photographed June, 1911. (Original.)

FIG. 3.—First cutting secured from one of the fields of alfalfa slightly injured by the attack of the weevil. Photographed June 2, 1911. (Original.)

INJURY WROUGHT BY THE ALFALFA WEEVIL.

offspring of parents developing during the preceding spring. Eight apparently fresh adults taken from the field on August 18 by Mr. Urbahns were observed on the 21st to have oviposited to the number of about 20 eggs, in confinement. Nine additional eggs were found on the 23d. August 29, 10 adults, also seemingly fresh and unrubbed, were confined in a glass vial, and the following day about 50 eggs were found in the vial. Under the same date 112 beetles, supposed from appearances to belong to the spring generation, were collected by another member of the force at an elevation of about 7,000 feet, and the following day 75 eggs were found in the box in which they were confined. Under the artificial conditions not all of these eggs hatched. This state of affairs continued and was observed by several of the men to occur up to the end of the season.

While the beetles go into hibernation in nearly perfect unrubbed condition, they emerge in spring with scales and pubescence removed to such an extent that they are almost black in color, smooth, and shining. This appearance so contrasts with that of the newly-emerged adults of the new generation that the latter can be easily separated at sight, and it was these latter that were again and again observed to oviposit and their eggs to hatch out larvæ.

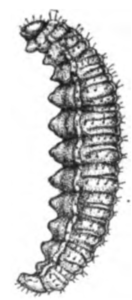


FIG. 5.—The alfalfa weevil: Larva. Much enlarged. (Author's illustration.)

## THE LARVA.

The larval stage is shown in dorsal view in figure 4 and in lateral view in figure 5. It is during this stage that the pest accomplishes the greatest destruction, although the beetles are of themselves capable of ruining the second hay crop of alfalfa.

Mr. Titus [1] states that soon after hatching from the eggs the larvæ, which at that time are quite active, begin feeding in the interior of the stalk, sometimes remaining there for 3 or 4 days, and isolated examples have been found that have passed into the second stage, still inside the stalk. Larvæ have been found inside hollow stems several inches away from the place where they hatched, working their way upward, and later issuing through a feeding puncture. Usually after 3 or 4 days they come out and work their way up the outside of the stems and conceal themselves in a leaf bud, usually at the tip of the plant.

That the very young larvæ are capable of traveling considerable distances to reach their food supply is not only indicated in Mr. Titus's published statement, but emphasized by the observations of Mr. C. N. Ainslie under date of April 28, 1910. The actions of newly hatched

[1] Bulletin 110, Utah Agr. Coll. Exp. Sta., pp. 39, 40, September, 1910.

larvæ, as observed by him, were remarkably vigorous, very young ones exhibiting great energy as travelers. Their mode of progression is to reach forward and then, with a slight hump, to bring up the rear part of the body. The head is at once thrust forward again. About one move is made per second, and three propulsions will carry the body forward 1 mm. When in doubt as to the direction to be taken, the larva elevates the head and swings it from side to side until some decision is reached, when the journey is resumed. The larvæ are positively phototropic.

After working their way upward on the alfalfa stems the larvæ begin to feed close down between the opening buds on the unfolding leaves. Their manner of feeding there, as observed by Mr. Ainslie, was by scraping off the epidermis with a sort of burrowing motion, leaving only the veins and fragments of uneaten tissue. This selection of the terminal buds may be in part due to the shelter offered as well as to the more tender and succulent nature of the plant growth. Large numbers of young larvæ may, however, be found feeding among the unfolding buds without being easily seen. This feeding is further described by Mr. Titus [1] as follows:

> In feeding, the larvæ bore holes into the buds [see fig. 4], working their way in until they are often completely concealed inside the opening bud. The plant then sends out other buds below this point, and usually other young larvæ are present to destroy these, so that at times the growing tips of the plants become so injured as to give these tips the appearance of a gall. As many as 15 young larvæ have been found feeding in the terminal bud of one stalk. Sometimes, before they are fully developed, in the second stage, they pass out onto the leaves, at first eating the upper epidermis only.

The larvæ, after the usual habit of those of the genus to which it belongs, either cling around the edge of the leaf or feed in a curved position. This continual eating off of the fresh growth keeps the alfalfa so reduced that it does not produce a first crop. Seriously affected fields are shown in Plate III, figure 1, and Plate IV, figures 1 and 2, while a field that has not suffered from such attack is shown in Plate IV, figure 3. From these illustrations a good idea of the damage done by the larvæ to the first crop of alfalfa may be obtained.

## LARVAL PERIOD.

From about 5 to 8 days after hatching from the egg the skin of the larva splits and the old skin is pushed off, leaving the larva in a new dress. This process is repeated after a period of from 12 to 20 days and again after about 12 to 30 days, as observed by Mr. Titus. Mr. Ainslie in some instances got pupæ in 18 to 20 days during May, 1910. These variations in time are probably largely due to temperature, which again may be due in part to elevation.

[1] Bulletin 110, Utah Agr. Coll. Exp. Sta., pp. 40-42, September, 1910.

When the larva is fully grown, it ceases to feed and seeks out some place in the crown of the plant among the litter and trash or on the ground among similar material, where it spins a cocoon (fig. 6).

## Cocooning and Pupating.

The cocoon is composed of fine white threads and the construction by the apparently blind larva was in part observed by Mr. Ainslie, who describes its movements as follows: A larva was seen moving about in its snow-white, almost transparent, gauzy, unfinished cocoon. It proved to be spinning a closer mesh from within. Instead of spinning the silk from a gland that opened into its mouth, as was supposed, the fluid from which the silk is made is taken into the mouth apparently from a gland in the caudal segment. The larva applied its mouth to an opening or gland close to the anus, appeared to move its jaws slightly, and then, with a quick movement of the body, was straightened out as much as possible in its confined space, and instantly the head was applied to the inner network of the cocoon. A slender glistening thread was seen leaving the mouth, being attached glutinously to each thread that it crossed. The larva worked rapidly and nervously, nearly always carrying its new thread in a rather straight line. From 30 to 50 seconds were required to discharge a single mouthful supplying thread for one-third or one-half a revolution inside the cocoon.

Fig. 6.—The alfalfa weevil: Cocoon. Much enlarged. (Author's illustration.)

When all the supply was exhausted, the head groped aimlessly about for a few seconds, then was applied to the caudal gland as before. The body would then straighten with a quick movement and almost instantly the thread would be again flowing as before. The new thread was guided skillfully across the meshes, rarely if ever following the line of a thread already laid. A very slight jar would cause a sudden halt for perhaps half a minute, then the operation would hesitatingly proceed. As the irregularly oval cocoon is too small in any diameter to allow the larva to straighten out, the larva moved about by thrusting its small head into a mesh, swinging the body into the desired position; the head would then be moved to another mesh and the operation repeated. The fluidity and amount of the silk must vary as spinning progresses, the silk becoming more viscous or less copious as the cocoon approaches completion.

The pupal period, according to Mr. Parks's notes, during the middle of May lasts about 9 days, the larvæ spinning their cocoons about 5 days before pupating. (A pupa is shown in fig. 7.) At the end

of the season, however, during August, when the temperature is higher, the pupal period averages only 3 days, the cocoon being spun only about 36 hours before the larva pupated. The adult leaves the cocoon about a day after transformation, and unlike others of this genus does not devour the cocoon. Although the insect has passed through its transformation from egg to adult the injury it causes is by no means ended. The beetles themselves not only feed upon the young growth (fig. 8), but gnaw off the bark of the stems, and, together with the larvæ still in the fields, in this way prevent the alfalfa from springing up for weeks after the first crop of hay has been removed. Two of such fields are shown in Plate V, figure 3, and Plate VI, figure 3, the ground being almost as bare of growing plants as in figure 1, Plate VIII, where the ground has been torn up with a spring-tooth harrow. The beetles sometimes cluster in great numbers upon a single plant, as illustrated in figure 8.

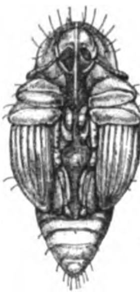


FIG. 7.—The alfalfa weevil: Pupa. Much enlarged. (Author's illustration.)

**FOOD PLANTS.**

In a series of experiments carried out by Mr. P. H. Hertzog, larvæ of *Phytonomus posticus* were placed in cages on various food plants, both alone and with alfalfa, and it was found that they fed freely upon the following plants, in combination with alfalfa:

Sweet pea, *Lathyrus odoratus;* Utah milk vetch, *Astragalus utahensis;* string bean, *Phaseolus vulgaris;* obtuse-leaved vetch, *Vicia* sp.; narrow-leaved vetch, *Vicia* sp.; white clover, *Trifolium repens;* red clover, *T. pratense;* alsike clover, *T. hybridum;* yellow sweet clover, *Melilotus indica* (?); white sweet clover, *M. alba; Medicago lupulina; M. echinus; M. hispida nigra; M. hispida confinis; M. hispida terebellum; M. muricata; M. orbicularis; M. scutellata;* black locust, *Robinia pseudacacia;* fenugreek, *Trigonella fœnumgræcum.*

The following is a list of plants eaten by the larvæ when no other food was offered, but refused when offered together with alfalfa:

*Hedysarum mackenzii; Astragalus oreophilus;* downy lupine, *Lupinus;* sp. chick pea, *Lathyrus sativus; Vicia atropurpurea; Vicia dispema;* spring vetch, *Vicia sativa alba;* hairy or winter vetch, *Vicia villosa;* spider plant, *Cleome serrulata.*

FIG. 8.—The alfalfa weevil: Adults clustering on and attacking sprig of alfalfa. About natural size. (Author's illustration.)

The following plants were refused by the larvæ even when no other food was offered:

Everlasting pea, *Lathyrus latifolius;* round-leaved mallow, *Malva rotundifolia;* birdsknot grass, *Polygonum aviculare;* garden pea, *Pisum sativum;* lamb's-quarters, *Chenopodium album;* purslane, *Portulaca oleracea;* prickly lettuce, *Lactuca scariola,* perhaps var. *integrata;* ground cherry, *Physalis longifolia* (?); bitterweed, *Ambrosia psilostachya;* bitterweed, *Ambrosia trifida integrifolia;* rough pigweed, *Amaranthus retroflexus.*

## MIGRATION AND DIFFUSION.

There are two periods during which the adult insects migrate, more or less aided by the winds and perhaps to a less extent by other agencies. Such as have not hibernated directly in the alfalfa fields become active in early spring and fly about freely, seeking such fields in which to deposit their eggs. This spring migration covers a considerable period of time—about six weeks, as estimated by Mr. Titus. As the females are more or less heavily laden with eggs, however, the flight of the individual is perceptibly shorter than in the second, or summer, migration, the season for which begins early in June and continues for three or four weeks. Another reason for the shorter flight in spring is that the beetles are searching about, not for places of hibernation, but for breeding places. Having found these, they naturally would not go farther unless carried by the winds. In case of a summer flight, however, the conditions are altogether different. This is the season during which most nomadic insects become more widely diffused. At this time the beetles fly high in the air and apparently over long distances. They are also to be observed crawling about in almost every situation, as with the larger species, *Hypera punctata*, which may be observed wandering aimlessly over the pavements in the midst of large cities. Then, too, they appear to float about freely on the surface of water, and are doubtless carried long distances down stream by the current. We know this is true in the case of irrigating ditches and canals, and it is also true of the larger species just mentioned in case of streams in the East. This habit of the beetles in hiding themselves away in any crevice or aperture that will accommodate them doubtless has considerable to do with their diffusion. As a matter of fact, however, it is absolutely impossible to lay down any law that appears to regulate the diffusion of the insect. There are instances where it would seem almost impossible to prevent the distribution of the pest, and yet most careful examination has failed to reveal anything of this sort. For a considerable time after the alfalfa weevil became abundant about Salt Lake and Murray hay was shipped from these points to Ely, Nev. This, too, in the midst of the season, when it would seem impossible to transport hay from these points to its destination without carrying greater or less numbers of the weevil. Notwithstanding this, years have gone by, and during the summer of 1911 two assistants examined the country about Ely most carefully without finding a single alfalfa weevil or any indications that it had ever existed there. While it is possible to account for the spread of the insect theoretically, we can not as yet account for its diffusion to the northeast into adjacent sections of Wyoming and Idaho. It does not appear to have entered Idaho by way of the Cache Valley, although Mr. Titus found beetles on a coal car at

Cache Junction in 1910. It does, however, occur in the Bear River Valley from Evanston, Almy, and Lyman, Wyo., northward into Bear Lake County in extreme southeastern Idaho. Previous observations would indicate that by a natural diffusion the insect has spread a distance of about 30 miles each year. As a matter of fact, the beetles are continually being found where least expected, and they have not been found where, judging from their habits, we would feel most confident of their occurrence.

The most rapid dispersion of the insect during the last two years has been toward the northeast from the original point of infestation in the Salt Lake Valley. Its injury is now noticeable wherever alfalfa is grown in the river valleys east of Ogden to the Wyoming State line and northward to the southern extremity of Bear Lake. It is known to occur, however, as previously stated, as far north as Cokeville, Wyo., and southward to Evanston and Lyman, where specimens were taken during the summer of 1911. This northeastward trend of diffusion in the weevil must be considered in connection with prevailing southwest winds at the time when the beetles are flying, and, in fact, careful search over the newly infested territory seems to render it highly probable that to this cause is due this northeastward diffusion. The finding of individual larvæ well scattered over Wyoming fields with little or no indications of introduction by human agencies, together with the finding of larvæ in an irrigated valley isolated from other cultivated crops by 35 miles of dry desert country, are conditions hard to explain in any other way than that the south winds of spring and summer have resulted in carrying flying beetles over low mountain ranges to fertile fields beyond. To just what extent the winds are able to carry the adults into new territory is not known, but at any rate migration in other directions has taken place much less rapidly.

## FIELD EXPERIMENTS IN DESTROYING THE ALFALFA WEEVIL.

Several extended series of experiments in destroying the alfalfa weevil were carried out at various points in the infested territory in Utah, but only those that have shown the best results will here be mentioned.

Quite naturally, a measure that will destroy a greater or less number of the insects and at the same time encourage the growth of the plant, and is of practical application, will not only be the most attractive one to the farmer but will result in a double benefit. For this reason disking was looked upon as probably offering the best results. It was thought that by disking and spraying a more rapid growth of the alfalfa plants would be secured, and by following this with the use of a brush drag a great many of the larvæ would be crushed and destroyed. Mr. Ainslie's observations made in 1910

indicate, however, that the brush drag does not destroy as many of the larvæ as one would suppose, and for this reason some harsher measures have been put into application during the season of 1911.

### Street-Sweeper Experiments.

The ordinary street sweeper, such as is used in our cities, appears to be a most thorough measure of destroying the pupæ. This much was determined by the Utah Experiment Station. A street sweeper (Pl. V, fig. 1) was used in a field on June 22, 1911. While examinaation showed that the result of this treatment, at this time, was to kill most of the larvæ and pupæ, it did not kill a great percentage of the adult weevils, which had already developed in large numbers. It would have been much better had this work been carried out about two weeks earlier; not only the condition of this field but of others in the neighborhood treated between June 14 and July 1 indicated that considerable good had resulted from this treatment even at this late season. On another farm, owned by Mr. Breeze, southwest of Salt Lake City, a field was swept with the street sweeper about the 14th of June with a view of interfering with the work of the weevil.

By July 7 the alfalfa in the Breeze field was about 20 inches high with very few weevils present. (See Pl. V, fig. 2.) Twenty days later the alfalfa was 30 inches high and in full bloom, being ready for the taking of a second crop. Just across the road from this farm was a field where no treatment whatever had been applied against the weevil. In this field the alfalfa plants were only about a foot in height and very much delayed (Pl. V, fig. 3). This seems to indicate that as a protection for the second crop the measure has considerable value. The drawback here is in the expense of a street sweeper, although of course where the members of a community club together, or in case of very large alfalfa fields of several hundred acres, the first cost of this sweeping machine would not constitute such an important item.

### Wire-Brush Experiment.

A 13-acre field of alfalfa 7 years old had been disked in the spring of 1910. The first crop of alfalfa was reported to have been reduced to one-half by attack of the weevil. A weevil-collecting machine had also been used on this first crop, but there were still enough of the weevils left in the field to greatly retard the second crop. It was disked and dragged again and a fairly good yield of the second crop was secured. This was also true of the third crop in this same field.

On May 15, 1911, there was a good stand of alfalfa in this same field. One irrigation had at this date been applied. The plants were a little over a foot in height, and while at the time, May 15, they were in fairly good condition they were heavily infested with weevil larvæ. The gathering machine was used twice between the 17th and

25th of May, and observations made at the time indicate that while many of the full-grown larvæ were collected, most of the smaller ones were left among the buds. On May 29 the field received a second irrigation. The larvæ at this time were very abundant; the gathering machine, too, had retarded the growth of the plants by breaking off the growing tips and some of the plants themselves had been broken down by the collecting machine. As a result the alfalfa had apparently made little or no growth since about the 22d, and its value as forage was at that time rapidly decreasing.

A wire-brush machine (Pl. VI, fig. 1) was constructed by Mr. L. Hemenway by bolting about 30 pieces of No. 8 steel wire 7 inches long between iron clamps on each spring tooth of an old spring-tooth cultivator. The ground was gone over with one of these on June 1, as soon as the hay had been removed. The jumping action of the spring, together with the wire brushes, proved very effective in crushing larvæ and pupæ among the stubble. The field was then gone over with a plank leveler, shown in Plate VIII, figure 2, with square iron edges bolted to a plank. June 7, the field received another brushing with the wire-brush machine, which crushed cocoons and larvæ. By June 13 the second crop in this field had started nicely with very few weevils present. In another field near by no attempt had been made to treat it or to remove the weevil, and this field was taken as a check on the one under treatment. An examination at this time showed that when the former field was in good condition, with few larvæ, the field that had received no treatment was bare and brown from their attack.

On June 22 the second crop of alfalfa on the treated field was about 8 inches high, while the unworked field was still bare and its condition, on June 27, is shown in Plate VI, figure 3. By the 27th the alfalfa in the treated field was about 1 foot in height (see Pl. VI, fig. 2), the stand extra good, and the treatment had seemed to free the field from weeds and other foreign growth. By July 7 the plants were about 2 feet in height, while, of course, both the adults and larvæ could be found to some extent in this field. July 27 the second crop harvested 2 tons per acre, selling at $9 per ton in the field. The field at time of harvest of second crop is illustrated in Plate VII, figure 1. The unworked field, however, was making an inferior second crop, coming just a little in advance of the third crop in the treated field.

From the treated field there was also a fourth crop of hay secured. The field was photographed on October 9, 1911, and the yield of hay is illustrated in Plate VII, figure 2. The condition of the check field a few days later, October 12, is shown in Plate VII, figure 3; here the second and third crops were both not only badly damaged, but so delayed in growth of alfalfa that, as shown by the illustration, no fourth crop was secured at all.

FIG. 1.—Street sweeper in operation on alfalfa field after first crop was removed. Larvæ and pupæ were crushed by the rotary brush. Photographed June 14, 1911. (Original.)

FIG. 2.—Second crop ready to cut in the field on which street sweeper was used June 14, 1911. Good stand and good crop. Photographed July 27, 1911. (Original.)

FIG. 3.—Second crop of alfalfa growing on field where no treatment was given. Crop short and about two weeks behind that of the field shown in figure 2. Photographed July 27, 1911. (Original.)

FIELD EXPERIMENTS AGAINST THE ALFALFA WEEVIL.

FIG. 1.—Wire-brush cultivator in operation on alfalfa field after first crop was removed. The brushes crush the larvæ and pupæ on the ground at this time. Photographed June 7, 1911. (Original.)

FIG. 2.—Second crop of alfalfa growing nicely as a result of treatment given. (See fig. 1, above.) Larvæ and pupæ were killed, so that second crop suffered only slight injury. (Original.)

FIG. 3.—Condition of untreated fields about June. Photographed June 27, 1911. (Original.)

FIELD EXPERIMENTS AGAINST THE ALFALFA WEEVIL.

FIG. 1.—Second crop of alfalfa, estimated at 2 tons per acre, secured from field treated with wire-brush cultivator. Photographed August 2, 1911. (Original.)

FIG. 2.—Fourth crop of alfalfa secured from field where brush cultivator was used. Photographed October 9, 1911. (Original.)

FIG. 3.—Condition of field used as check (Pl. V, fig. 3). The second and third crops on this field made little growth and were much delayed, so what would correspond to the fourth crop was caught by frost. Photographed October 12, 1911. (Original.)

FIELD EXPERIMENTS AGAINST THE ALFALFA WEEVIL.

FIG. 1.—Alfalfa field after first crop was removed, severely disked preparatory to application of "mudding" process against the alfalfa weevil. Photographed June 21, 1911. (Original.)

FIG. 2.—Following the irrigation water with a drag, to "puddle" the weevils in the mud. Photographed June 22, 1911.

FIELD EXPERIMENTS AGAINST THE ALFALFA WEEVIL.

FIG. 1.—Second crop of alfalfa in field treated by "mudding" process. Crop growing well and not seriously damaged by the alfalfa weevil. Photographed June 10, 1911. (Original.)

FIG. 2.—Condition of untreated fields at time photograph shown in figure 1 was taken. The alfalfa weevils have prevented the second crop from starting. Photograph taken July 10, 1911. (Original.)

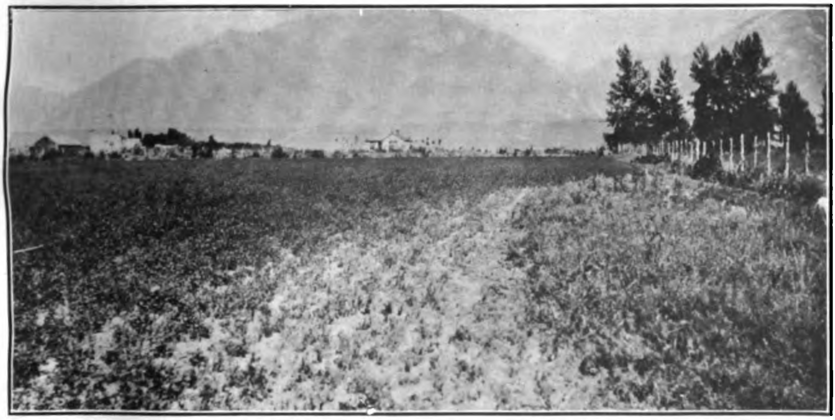


FIG. 3.—Patch of first crop left in field shown in figure 1, illustrating how the larvæ were disseminated from the first crop into the field where the weevil had been killed by the "mudding" process. Photograph taken July 10, 1911. (Original.)

FIELD EXPERIMENTS AGAINST THE ALFALFA WEEVIL.

## Cultivation in Connection with Irrigation.

For an experiment to determine the value of cultivation in connection with irrigation in controlling the alfalfa weevil a field was selected on a farm belonging to Mr. Hansen, 1 mile southeast of Sandy, Utah, containing 16 acres. The soil was a light sandy loam. Some of the weevils had been noticed in this field in 1908 and also in 1909, while the first crop of 1910 was severely damaged and the second also suffered considerable loss. May 11, 1911, the field was irrigated, the infestation being considered heavy. The first crop was cut during the week ending June 10. The plants were about 9 or 10 inches high and the hay yielded less than 1 ton per acre of very poor quality. This field was again irrigated and the more elevated portion of it worked with a spring-tooth harrow while the surface was still soft from the irrigation. This treatment was repeated and when finished the field had very much the appearance of any cultivated field, little resembling a meadow. (See Pl. VIII, fig. 1.)

On June 22, while the land was still soft and muddy, a light irrigation was given it, so that the water collecting in the lower portion of the field stood to a depth of 2 or 3 inches. Four horses were hitched to a plank leveler and dragged through this mud, as shown in Plate VIII, figure 2. This thoroughly "puddled" the weevil in all of its stages beneath the surface.

By the 30th of June a second crop was starting very nicely while neighboring untreated fields were being retarded by the continued attacks of the weevil. Ten days later the plants were about 12 inches high with very few of either larvæ or beetles present. However, a patch had been left uncut and unworked in one corner of this field and here the first crop of alfalfa was still standing. (See Pl. IX, fig. 3, at the right.)

There were a great many larvæ and beetles on this patch, which disseminated themselves into the growing alfalfa where the mudding process had been practiced, destroying a strip about 1 rod in width, clearly shown in Plate IX, figure 3. The second crop in this field, July 10, 18 days after the mudding experiment was carried out, was about 14 inches high. (See Pl. IX, fig. 1.)

In a near-by untreated field at the same time, four weeks after the first cutting was made, the condition is shown in Plate IX, figure 2.

## Burning Machine.

Several field experiments were carried out with a machine constructed with the idea of burning over alfalfa fields after the removal of the first crop for the purpose of destroying the weevils in any stage of development remaining in the field. The machine, as shown in Plate X, figure 1, consisted of an iron frame 9 feet square, 12 inches

high in front, and adjustable in the rear. The top was of light sheet iron bolted to the frame.

Oil was pumped from a barrel in the conveyance to which this machine was attached and forced through a rubber hose into a supply pipe which fed the nozzles and burners underneath. The oil under pressure came forth from the burners as a mist of fire blowing into the stubble and against the ground.

The sheet-iron cover served to hold the heat down while this oven passed slowly over the surface. In its unperfected state the machine did effective work and offered ideas of value, warranting the construction of more efficient burners.

In fields where there was a clean stand of alfalfa stubble this machine did very well in burning vegetation and destroying all insect life above the surface of the ground. Where many weeds, especially dandelions, were present, the insects found protection under the green leaves. Where parts of fields were burned over, the unburned area showed no growth for several weeks on account of the continued weevil attack. The burned area turned green within a very much shorter time.

## REDUCTION IN QUALITY OF HAY CAUSED BY THE ALFALFA WEEVIL.

While studying the alfalfa weevil on various farms in the Salt Lake Valley during the month of April, 1911, it was found that many farmers, through a shortage of forage, were feeding the weevil-injured hay of the first crop to their horses. This hay contained so many old cocoons and was so dusty from larval excrement and dead bodies of weevil larvæ as to render it unfit as feed for horses. On several occasions horses were observed coughing from the effect of this dust. In fact, many farmers consider the first crop from severely infested fields almost valueless as horse feed.

On June 12, 1911, at Alpine, Utah, when the new hay from the first crop was fed to work horses these began coughing almost immediately after starting to feed upon this injured hay. The hay contained large numbers of dead weevil larvæ, some still on the skeletonized leaves and some in the freshly spun cocoons. On September 13 hay from the first crop, in stack, was examined at Layton, Utah, and found to be very dusty, containing many dead weevil larvæ and also pupæ.

## NATURAL ENEMIES.

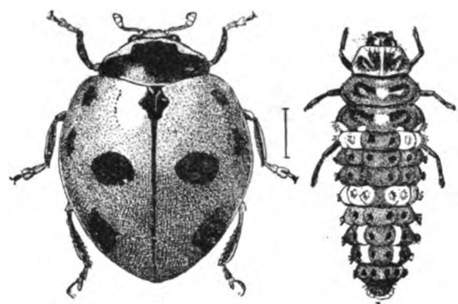
The natural enemies of the alfalfa weevil consist of vertebrates and invertebrates. The former have been studied by assistants of the Bureau of Biological Survey, and a list of species observed to attack the weevil is given herewith.

The invertebrate enemies are divided between native species and those imported from Italy, the native being largely predaceous and the foreign all parasitic.

Besides these, there are two fungous enemies, both of which affect the insect to a greater or less degree.

## INVERTEBRATES.

When a foreign species, like the alfalfa weevil, is introduced into a new country, some time is required for the native insects to find out that it is suitable for food, precisely as man himself would under the same circumstances have to learn what products of a new country were edible. Besides, he would most likely cultivate a taste for some of these things which at first were distasteful to him. Thus it is that native insect foes of introduced species begin slowly at first to prey upon them.



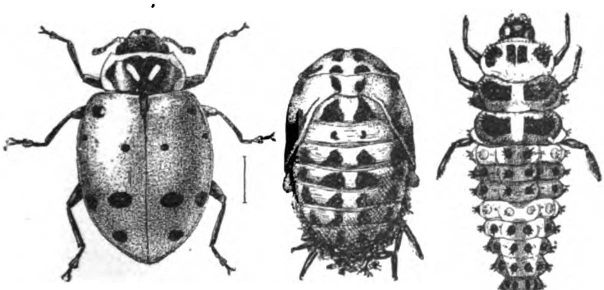
a b

FIG. 9.—Nine-spotted lady-beetle (*Coccinella 9-notata*): *a*, Adult; *b*, larva. Much enlarged. (From Chittenden.)

The following native predaceous insects have been found attacking and devouring the alfalfa weevil:

### PREDACEOUS ENEMIES.

A species of tiger-beetles, *Cicindela imperfecta* Lec., was in one instance observed to feed upon an alfalfa weevil larva in the field. Several other individuals belonging to the same species when taken to the laboratory readily devoured larvæ.



a b c

FIG. 10.—Convergent lady-beetle (*Hippodamia convergens*): *a*, Adult; *b*, pupa; *c*, larva. Enlarged. (From Chittenden.)

Three species of lady-beetles, *Coccinella 9-notata*, Hbst. (fig. 9), *Hippodamia spuria* Lec., and *H. convergens* Guér. (fig. 10), in the larval stage attacked and devoured half-grown larvæ of the alfalfa weevil in the fields. Larvæ so taken were brought into the laboratory and adults reared, from which specific determinations were made. In case of *H. spuria* the adult was also observed devouring larvæ in the field.

The malachid beetle, *Collops bipunctatus* (fig. 11), was repeatedly observed feeding upon the weevil larvæ in the fields.

The tenebrionid beetle, *Eleodes sulcipennis* Mann., was accused by farmers of feeding upon the larvæ of the weevil and when taken to the laboratory it readily did this in confinement. An allied species, *E. suturalis* Say, was observed by Mr. E. O. G. Kelly to devour chinch bugs in the neighborhood of Wellington, Kans. In the latter instance the beetles seemed to prefer the partially decaying leaves of corn under which the chinch bugs were hiding. It is probable that while these insects may devour a few of the weevil larvæ they prefer other and vegetable food.

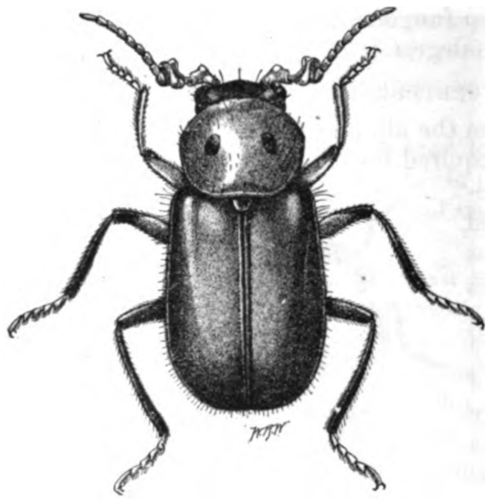


**Fig. 11.**—The two-spotted Collops (*Collops bipunctatus*): Adult. Enlarged. (Original.)

The predaceous mite, *Pediculoides ventricosus* Newp. (figs. 12, 13), was introduced from Indiana in March, 1911, but was afterwards found a sufficient distance away from the points of introduction to show plainly that it was already an inhabitant of Utah. The results

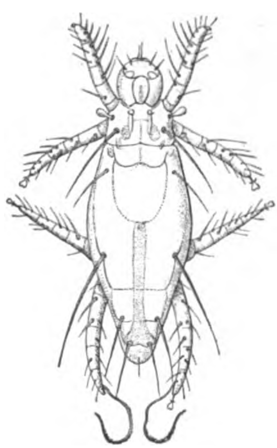


**Fig. 12.**—*Pediculoides ventricosus*, a mite predatory on the alfalfa weevil: Adult female before the abdomen has become inflated with eggs and young. In this condition the mite is nomadic and predatory. Greatly enlarged. (Redrawn from Brucker.)

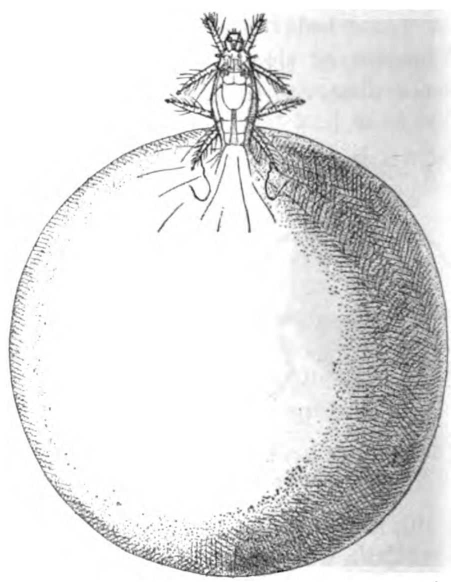


**Fig. 13.**—*Pediculoides ventricosus:* Adult female after the abdomen has become inflated with eggs and young. Greatly enlarged. (Redrawn from Brucker.)

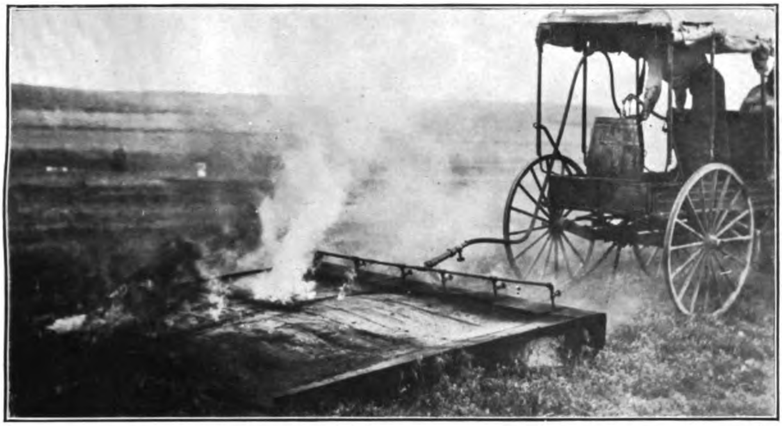


FIG. 1.—BURNING MACHINE EXPERIMENTED WITH AS A METHOD OF DESTROYING THE ALFALFA WEEVIL. (ORIGINAL.)

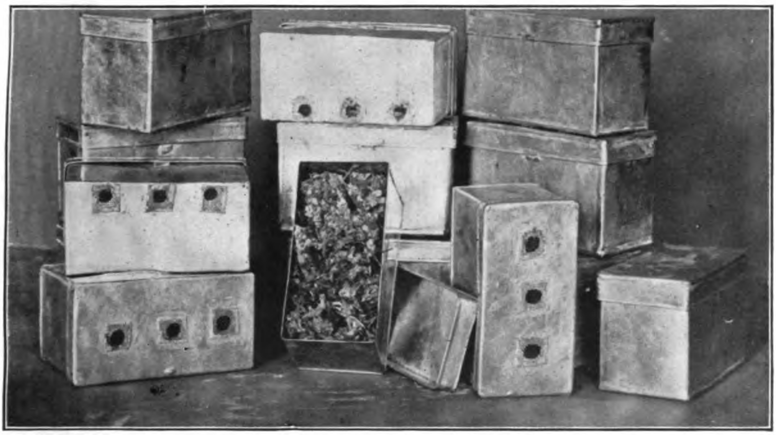


FIG. 2.—BOXES CONTAINING PARASITES OF THE LARVÆ AND PUPÆ OF THE ALFALFA WEEVIL, SHOWING HOW THIS MATERIAL WAS IMPORTED INTO THE UNITED STATES FROM ITALY. PHOTOGRAPH TAKEN JUNE, 1911. (ORIGINAL.)

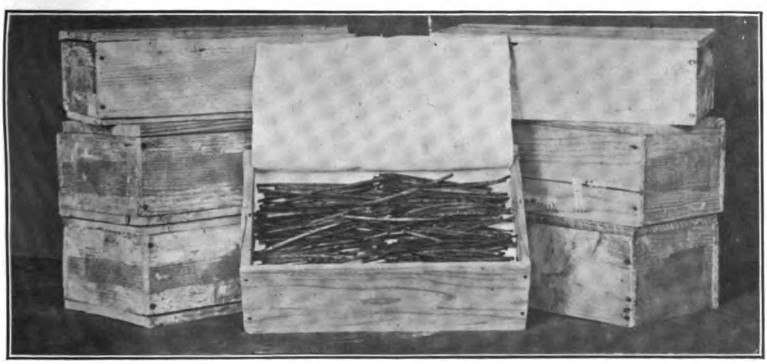


**FIG. 3.—BOXES OF PARASITE MATERIAL IMPORTED FROM ITALY WHICH CONTAIN EGG PARASITES OF THE ALFALFA WEEVIL. PHOTOGRAPH TAKEN MAY, 1911. (ORIGINAL.)**

of experiments with this mite, which is so effective in destroying the jointworm in the East, were unsuccessful, as it was found that the mites would not attack either the larvæ or the pupæ. They fed freely upon the eggs of the weevil, where these were easily accessible, but they seemed unable to gain access into many of the egg masses through the ordinary egg punctures. A single egg did not furnish sufficient food to bring one mite to maturity, and it would therefore necessarily perish; but where there were clusters of eggs in contact with each other, the female mite was able to shift her body about sufficiently to devour more than one egg and was thus enabled to reproduce. In the field, when placed in cages with an abundance of eggs of the alfalfa weevil, the mites appeared to make considerable headway in overcoming the weevil, but in no case could the effects of their attack be traced farther than 2 feet from the cage where they had been confined in the fields.

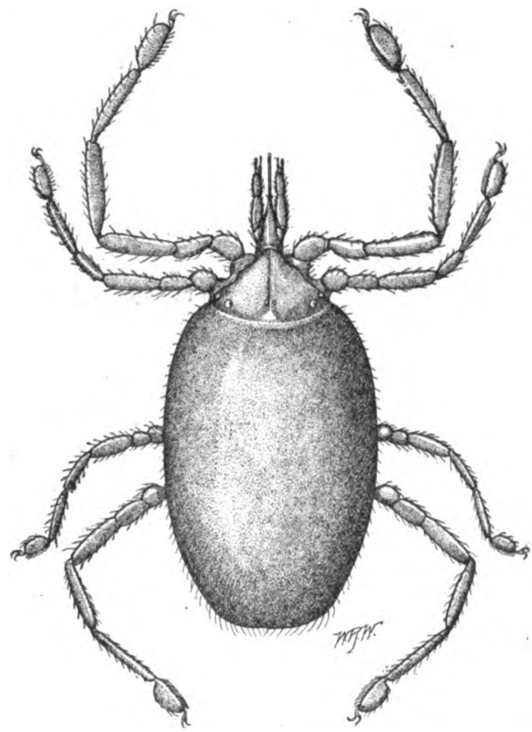


FIG. 14.—A predaceous mite, *Erythræus arvensis:* Adult. Greatly enlarged. (Original.)

A little mite (Trombidium) was found attached to the adult weevil beneath the wing covers, and while it was observed quite commonly in late summer and fall, so far as observations indicated it did not appear able to kill the host insect. A predaceous mite, *Erythræus arvensis* Banks (fig. 14), was found by Mr. Ainslie feeding on eggs of the weevil in the egg punctures. The economic value of this species is as yet very obscure. Spiders are occasionally found feeding upon the larvæ in the fields. Lace-wing flies (Chrysopa) fed upon the larvæ in confinement when forced to do so, but preferred aphides. They were not observed to attack the weevil in any form in the fields.

## A NATIVE TRUE PARASITE.

Only one specimen of a single species of a true parasite of the alfalfa weevil has so far been found in America. This was described by Mr. Viereck as *Ænoplegimorpha phytonomi*. It was found August 30, 1911, at Hoytsville, Utah, in the form of a cocooned pupa within the cocoon of the alfalfa weevil. The specimen was picked up from the surface of the ground in a badly infested alfalfa field and the adult parasite reared. The adult emerged September 3.

## INTRODUCED PARASITES.

Several species of parasites were sent over from the vicinity of Portici, Italy, by Mr. W. F. Fiske during April, May, and June, 1911.

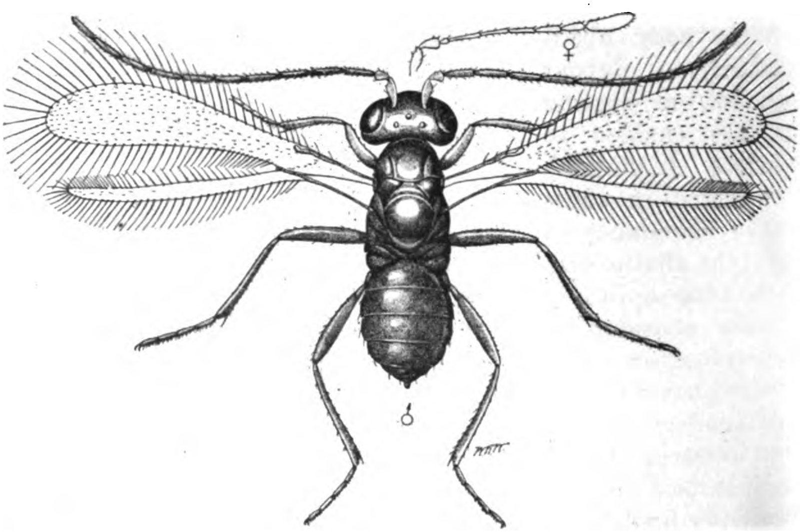



FIG. 15.—*Anaphes* sp., a mymarid egg parasite of the alfalfa weevil: Adult male; female antenna above at right. Greatly enlarged. (Original.)

The egg parasites were obtained by collecting stems of alfalfa containing eggs of the alfalfa weevil, placing these in boxes (Pl. X, fig. 3), and transporting them by cold storage on steamers bound for New York. On arrival from Europe they were promptly forwarded by refrigerator express to their destination, Salt Lake City, Utah, where they were at once taken either to the laboratory at Salt Lake City (Pl. XIII, fig. 1) or to the laboratory at Murray (Pl. XIII, fig. 2).

Parasites that attack the weevil after it has hatched and before it has developed to the adult were handled in much the same manner. The boxes in which they were consigned are shown in Plate X, figure 2. The time required to transport these boxes from Portici, Italy, to Salt Lake City, Utah, was from 16 to 21 days.

### Egg Parasites.

There were two egg parasites, one, a true egg parasite developing within the egg, and the second, a parasite the eggs of which are probably deposited in the alfalfa stems among, but not in, the eggs. The larva of the latter is predaceous on the masses of weevil eggs as placed by the female weevil, and among them it develops to the adult.

#### MYMARID EGG PARASITE.

A mymarid egg parasite, *Anaphes* sp. (fig. 15), was found in all of the seven shipments received from Italy. It was received in all stages of development, except perhaps the egg and adult, and was either left in the same boxes, these being perforated with holes and

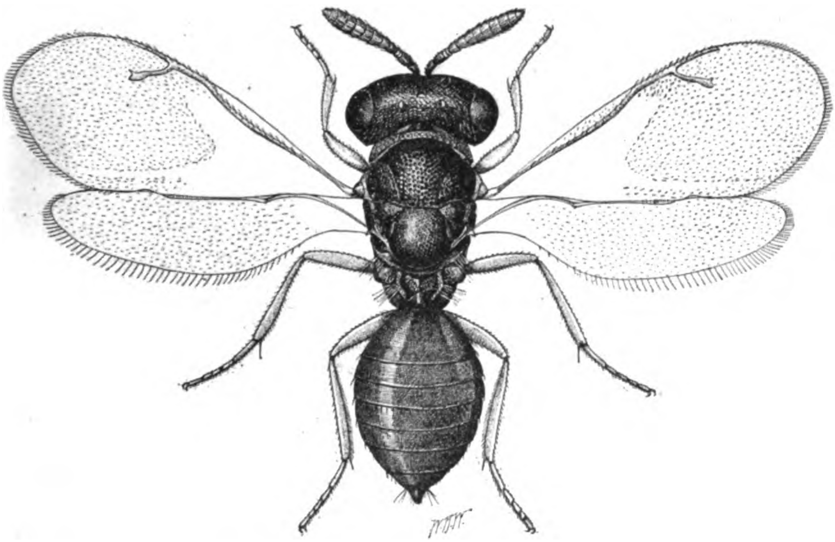


**Fig. 16.—Imported pteromalid egg parasite of the alfalfa weevil: Adult. Greatly enlarged. (Original.)**

glass tubes inserted (Pl. XI, fig. 2), or placed in specially prepared boxes (Pl. XI, fig. 3) which were also perforated and had glass tubes inserted. The parasites were reared from this imported material, and from the parent stock two generations were reared on American egg masses of the alfalfa weevil. The third generation, together with others of the first and second generations and natives from later shipments, was placed in field reproduction cages (Pl. XII, fig. 3) to the number of about 300. These cages were overstocked with eggs by confining numbers of weevils in them. After about 10 days the covers to these cages were removed, thus allowing the generation of parasites that developed within them to escape and scatter freely over the fields.

#### PTEROMALID EGG PARASITE.

A pteromalid egg parasite (fig. 16) was likewise found in all of the seven importations. The larva (fig. 17) feeds externally on the egg masses in the alfalfa stems, later transforming to the pupa (fig. 18).

The disposal and management of this species did not differ from that followed with the preceding, except that some of them were received too late in the season to use in the low valleys because the majority of the eggs of the weevil had already hatched. Owing to this the parasites were taken to places in higher elevations where eggs of Phytonomus were still abundant. Approximately 460 were placed in field cages like those previously mentioned and treated in the same way.

FIG. 17.—Larva of pteromalid egg parasite of the alfalfa weevil. Greatly enlarged. (Original.)

Mr. Fiske found this species to be very effective in controlling the alfalfa weevil in Italy.

PARASITES OF LARVÆ AND PUPÆ.

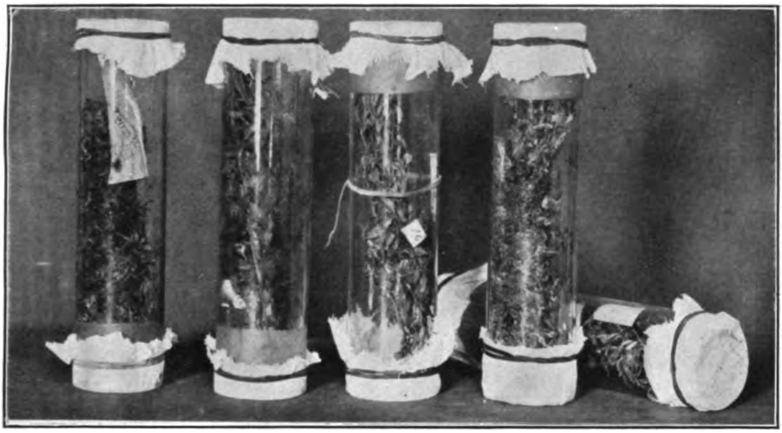
The parasites of the larvæ and pupæ of the alfalfa weevil, which were five in number, did not appear in the earlier consignments from Italy and were confined to the last three received at Salt Lake City May 16 to June 3. In these three shipments were metal boxes (Pl. X, fig. 2), which included only the cocoons of the alfalfa weevil. These boxes were especially devised to guard against the accidental escape of adult insects of any species en route.

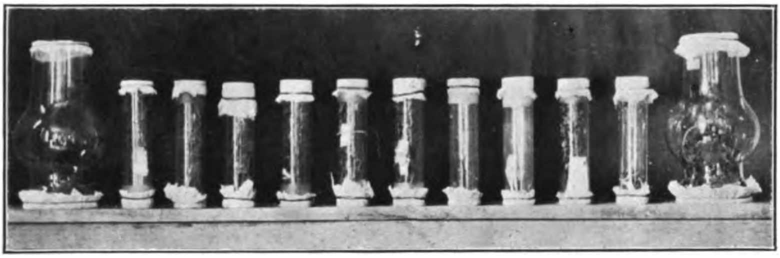
After being removed from the boxes in which the cocoons were received, they were placed in parasite boxes of the larger type (Pl. XI, fig. 3), where the parasites emerged and were separated from the weevils that had developed en route. Both weevils and parasites on emerging from the cocoons in the box would seek the light and appear in the glass tubes shown in the illustration, where they were readily separated and the weevils killed. The parasites were then transferred to glass cages (Pl. XI, figs. 1, 4) which had been previously well stocked with larvæ and cocoons.

FIG. 18.—Pupa of pteromalid egg parasite of the alfalfa weevil. Greatly enlarged. (Original.)

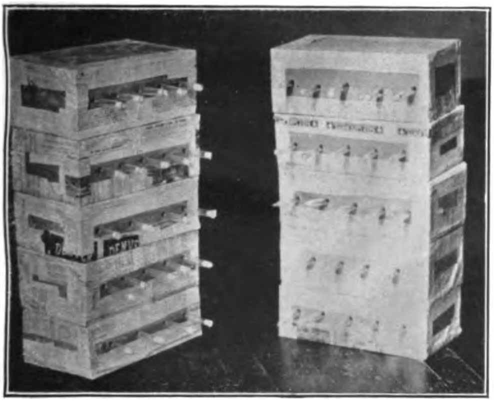
PTEROMALID LARVAL PARASITE.

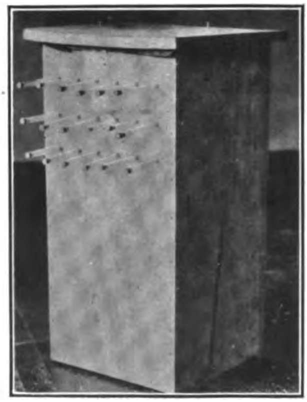
A pteromalid parasite of alfalfa weevil larvæ (fig. 19, female; fig. 20, male) was received in only the later consignments. Thus far it has not been possible to determine the species. In the laboratory rearings, preparatory to placing the parasites in the field cages, and later, the species was carried through five generations. (Fig. 21, *a* shows the pupa of the alfalfa weevil, with the egg (fig. 21, *b*) as it is placed on the pupa; fig. 22 shows the larva, and fig. 23 shows it destroying the pupa of the alfalfa weevil; fig. 24 shows the pupa of the parasite itself.) In order to accomplish this, however, it was necessary to secure weevil larvæ, as hosts for them, from high





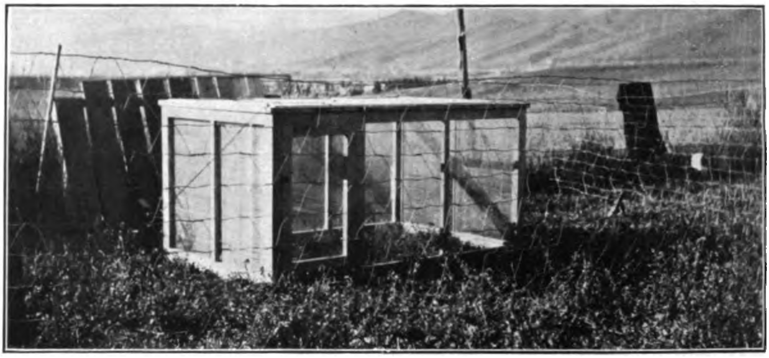
FIGS. 1 and 4.—Types of cages in which larval and pupal parasites of the alfalfa weevil were reared in the laboratory. Photograph taken during June, 1911. (Original.)

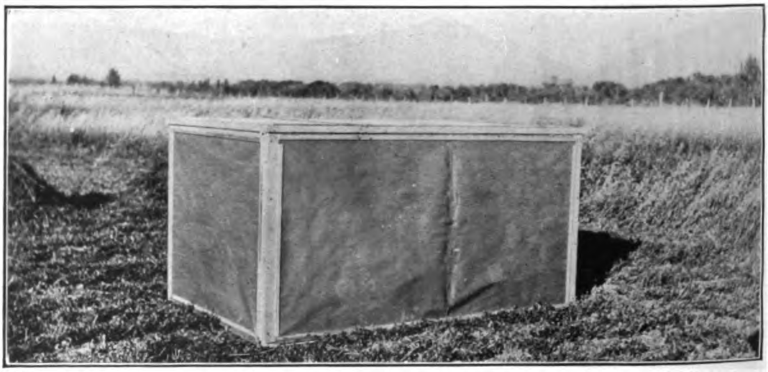




FIGS. 2 and 3.—Boxes sealed and fitted with glass tubes into which imported parasites emerged and were separated in the laboratory. Photograph taken during May and June, 1911. (Original.)

INTRODUCTION OF PARASITES OF THE ALFALFA WEEVIL.





FIGS. 1 AND 2.—FIELD CAGES USED IN HIBERNATION EXPERIMENTS ON THE ALFALFA WEEVIL. (ORIGINAL.)

FIG. 3.—PLANTING A COLONY OF IMPORTED PARASITES OF THE ALFALFA WEEVIL IN UTAH IN AN ALFALFA FIELD. PHOTOGRAPH TAKEN DURING JUNE, 1911. (ORIGINAL.)

elevations and bring these into the laboratory, thus supplying them artificially. There were 230 individuals liberated in field cages, the coverings of which were later removed, and 49 liberated directly

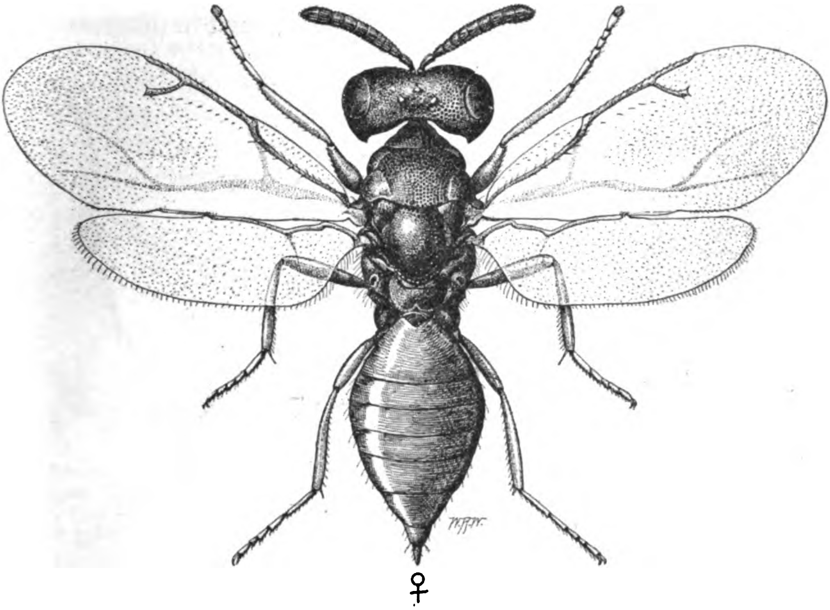



FIG. 19.—Pteromalid parasite of larva and pupa of the alfalfa weevil: Adult female. Greatly enlarged. (Original.)

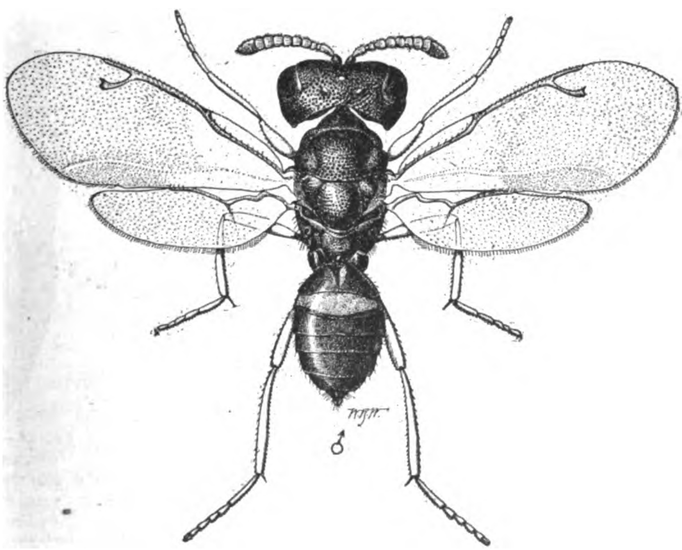



FIG. 20.—Pteromalid parasite of larva and pupa of the alfalfa weevil: Adult male. Greatly enlarged. (Original.)

into the open field. Observations have since shown that this species has actually colonized itself in the field; whether temporarily or permanently it remains to be seen.

### OTHER PARASITES.

The following three parasites came mainly in the last two shipments from Italy. The adult of one species (*Canidiella curculionis* Thoms.) (fig. 25) oviposits in the larvæ of the alfalfa weevil in different stages of development, but the offspring therefrom emerge from the cocoon spun by the weevil, the cocoons of the parasite always showing through the meshes of the cocoon of the weevil (see fig. 27). This species has two generations annually and hibernates as cocooned larvæ. The alfalfa stems from which the three species of parasites of this group were reared were also infested by *Apion pisi* Fab., and therefore some or all of the group may perhaps also parasitize this latter insect. Owing to its small size, however, as compared to the parasites, this seems rather unlikely.

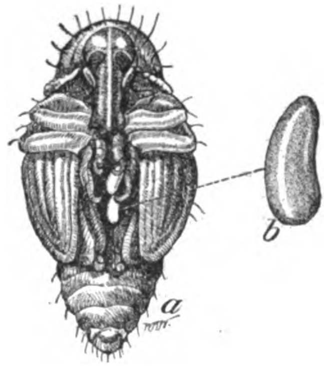


FIG. 21.—Pteromalid parasite of larva and pupa of the alfalfa weevil: *a*, Enlarged pupa of alfalfa weevil with eggs of parasite in place; *b*, egg, greatly enlarged. (Original.)

FIG. 22.—Pteromalid parasite of larva and pupa of the alfalfa weevil: Larva. Greatly enlarged. (Original.)

The two additional species reared with the preceding are not definitely determinable, but one is *Phygadeuon* sp., and the other may prove to be *Mesochorus nigripes* Ratz. Of this latter species Mr. T. W. Wassiljew, a Russian entomologist, under date of February 6, 1911, wrote us:

> I wish to say that I am able to give you only one instance of a parasite having been found, and that was in the vicinity of Taschkent (Turkestan), where I noticed in the past year [1910] that over 20 per cent of the larvæ of *P. variabilis* were attacked by an Ichneumon parasite. Unfortunately I do not know the name of this species of parasite at the present time, other than that it belongs to the Ichneumonidæ. Judging from the elliptical, thick-shelled cocoon it might possibly have been *Mesochorus nigripes* Ratz., which Mr. Ratzeburg (The Ichneumonidæ, III, p. 120) gives as a parasite of *P. rumicus*.

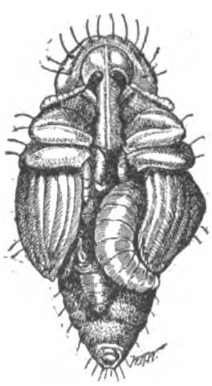


FIG. 23.—Larva of pteromalid parasite attacking pupa of alfalfa weevil. Enlarged. (Original.)

FIG. 24.—Pupa of pteromalid parasite shown in figures 22 and 23. Greatly enlarged. (Original.)

All of these parasites resemble each other to a certain degree, and figure 25 will suffice to illustrate them, for the present at least. At the present stage of this experiment in introducing parasites of the

alfalfa weevil the possibility of permanent establishment and future efficiency in the case of these species seems rather more encouraging than in case of the others. During June, 1911, 40 individuals reared from imported cocoons were placed in field cages artificially overstocked with weevil larvæ, the cage covers being removed later. Besides this, there is at present on hand a considerable amount of hibernating material (Pl. XII, figs. 1, 2) artificially reared in the Murray laboratory (Pl. XIII, fig. 2), which will be allowed to escape, naturally, into the alfalfa fields.

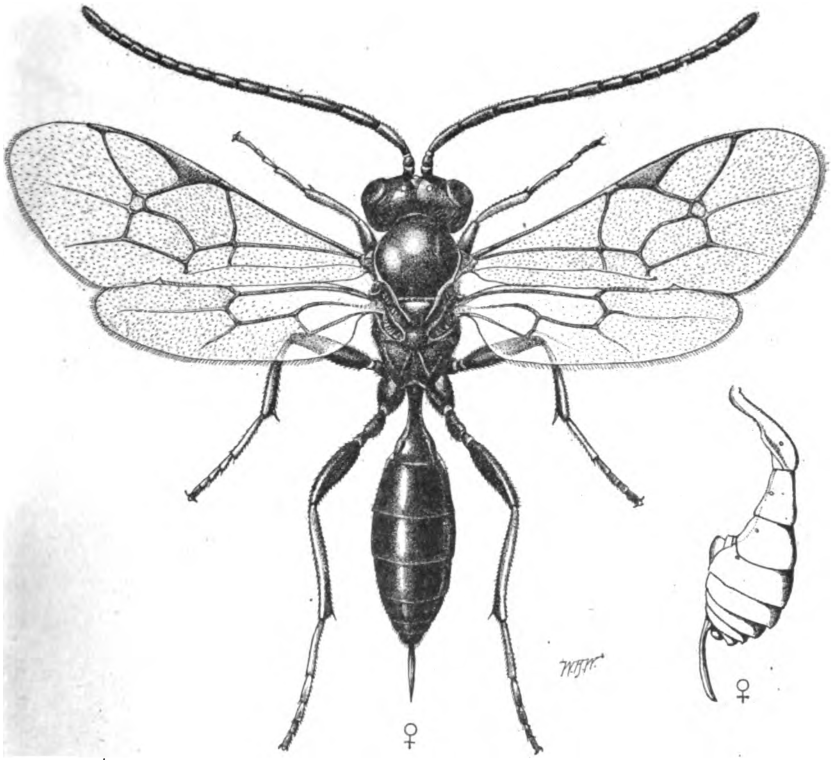



FIG. 25.—*Canidiella curculionis*, a parasite of the alfalfa weevil: Adult female; lateral view of abdomen of same below, at right. Enlarged. (Original.)

The parasite *Itoplectis masculator* Fab. (fig. 26) differs from the preceding by reason of the fact that it pupates entirely within the pupa of its host. It is known to be a primary parasite, but the number so far secured is too limited to warrant any discussion regarding it, or any predictions as to its future in America.

Of the eighth and last of these parasites, *Hemiteles* sp., very little is known either in Europe or America, and with the obscurity surrounding its habits it may prove to be either a primary or secondary parasite, a friend or an enemy of the others. It is therefore being handled with the utmost caution, none having been liberated either in the fields or in field cages.

## VERTEBRATES.

During the season of 1911 the Biological Survey, at the suggestion of the writer, kindly detailed an assistant, Mr. E. R. Kalmbach, to study the bird and other vertebrate enemies of the alfalfa weevil, and the following is a list of vertebrates found to feed on the alfalfa weevil in Utah, as determined by Mr. Kalmbach, May 7, 1911, to July 25, 1911.

Wilson's phalarope, *Steganopus tricolor;* killdeer, *Oxyechus vociferus;* valley quail, *Lophortyx californica vallicola;* mourning dove, *Zenaidura macroura carolinensis;* red-shafted flicker, *Colaptes cafer collaris;* Arkansas kingbird, *Tyrannus verticalis;* Say's

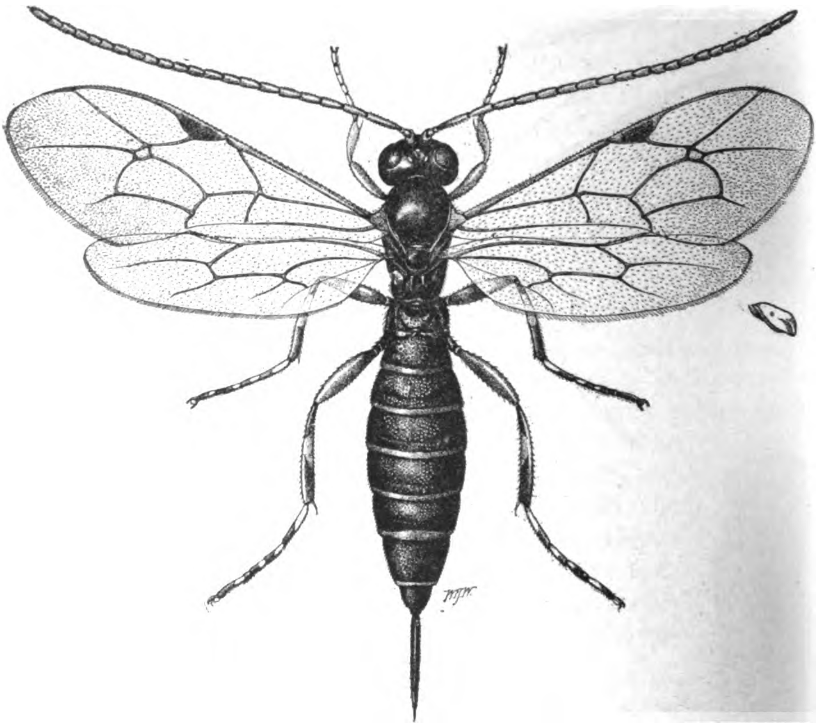


FIG. 26.—*Itoplectis masculator*, a parasite of the alfalfa weevil: Adult female; lateral view of first abdominal segment at right. Much enlarged. (Original.)

phoebe, *Sayornis sayus;* Traill's flycatcher, *Empidonax traillii;* desert horned lark, *Otocoris alpestris leucolæma;* magpie, *Pica pica hudsonia;* bobolink, *Dolichonyx oryzivorus;* cowbird, *Molothrus ater;* yellow-headed blackbird, *Xanthocephalus xanthocephalus;* thick-billed red-winged blackbird, *Agelaius phœniceus fortis;* Western meadowlark, *Sturnella neglecta;* Bullock's oriole, *Icterus bullocki;* Brewer's blackbird, *Euphagus cyanocephalus;* house finch, *Carpodacus mexicanus frontalis;* English sparrow, *Passer domesticus;* Western vesper sparrow, *Poœcetes gramineus confinis;* Western savannah sparrow, *Passerculus savannarum alaudinus;* Western lark sparrow, *Chondestes grammacus strigatus;* white-throated sparrow, *Zonotrichia albicollis;* Brewer's sparrow, *Spizella breweri;* Western chipping sparrow, *Spizella socialis arizonæ;* desert song sparrow, *Melospiza melodia fallax;* green-tailed towhee, *Oreospiza chlorura;* black-

FIGS. 1 AND 2.—LABORATORIES OF THE BUREAU OF ENTOMOLOGY, U. S. DEPARTMENT OF AGRICULTURE, AT SALT LAKE CITY AND MURRAY, UTAH. (ORIGINAL.)

headed grosbeak, *Zamelodia melanocephala;* rough-winged swallow, *Stelgidopteryx serripennis;* sage thrasher, *Oreoscoptes montanus;* Western robin, *Planesticus migratorius propinquus;* Rocky Mountain toad, *Bufo lentiginosus woodhousi;* leopard frog, *Rana pipiens;* salamander, *Amblystoma* sp.

## Fungous Enemies.

Whenever the larger species *Hypera punctata* (fig. 2) becomes excessively abundant east of the Mississippi River, myriads of these larvæ may be observed coiled about the uppermost tip of blades of grass or similar vegetation, where they soon die and become black. These are apparently destroyed by a fungus, *Empusa sphærosperma.* When investigations of the alfalfa weevil were first undertaken there were great numbers of these dead and dying larvæ to be found in Washington, D. C., in Potomac Park. They were gathered up and sent out to Salt Lake City and placed in the hands of Mr. Ainslie with the hope of introducing this fungus among the larvæ of the alfalfa weevil. The experiment appeared to have been a failure, and it was thought that the climate of Utah was too dry to enable this fungus to exist there. Later this larger species was found in Utah, as has already been stated, and during the spring of 1911 the fungus was found in the vicinity of Salt Lake City. Apparently, however, the fungus does not affect the larvæ to the same extent that it does here in the East, except after these have reached their full size and constructed their cocoons. Larvæ of the alfalfa weevil (fig. 5) and pupæ (fig. 7) soon began to be observed in the cocoon (fig. 6) dead and thoroughly permeated with this fungus. No individuals in any case were found dead excepting within their cocoons. On June 13 in the vicinity of Salt Lake City it was estimated that one-fifth of the cocoons contained dead larvæ or pupæ. In the Weber Valley, about Hoytsville, Utah, on the last of August, it was found that of 580 cocoons examined 258, or 44.5 per cent, were dead, partly at least because of infestation by this fungus. Examination at another point showed that 38 per cent had apparently died from the same cause. To all appearances, then, this was more effective in killing the alfalfa weevil than all other natural enemies combined.

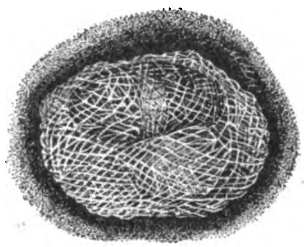


FIG. 27.—Cocoon of the alfalfa weevil showing cocoon of the parasite *Canidiella curculionis* within. Much enlarged. (Original.)

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 113.

L. O. HOWARD, Entomologist and Chief of Bureau.

# THE PRINCIPAL CACTUS INSECTS OF THE UNITED STATES.


BY

W. D. HUNTER,

*In Charge of Southern Field Crop Insect Investigations,*

F. C. PRATT,

*Late Assistant Entomologist,*

AND

J. D. MITCHELL,

*Agent and Expert.*



ISSUED DECEMBER 19, 1912.

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# LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
*Washington, D. C., May 3, 1912.*

SIR: I have the honor to transmit herewith a manuscript entitled "The Principal Cactus Insects of the United States," prepared by Messrs. W. D. Hunter and J. D. Mitchell, of this bureau, and the late F. C. Pratt, who for many years was in the employ of the bureau.

In the work of the Bureau of Plant Industry on the utilization of the prickly pear as a farm crop it became evident that insect injury in plantings was of considerable importance. This observation was made by Mr. David Griffiths. In 1907 he brought the matter to the attention of the Bureau of Entomology and the investigation upon which the present manuscript is based was begun. During the work the bureau has profited by the close cooperation of Mr. Griffiths, and many of his observations are included in this report.

I recommend that this manuscript be published as Bulletin No. 113 of the Bureau of Entomology.

Respectfully,

L. O. HOWARD,
*Chief of Bureau.*

Hon. JAMES WILSON,
*Secretary of Agriculture.*

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# THE PRINCIPAL CACTUS INSECTS OF THE UNITED STATES.

## INTRODUCTION.

The cactus plants of the genus Opuntia are among the most striking objects to be seen in semiarid and arid regions. These plants, which are extremely picturesque, are accorded a prominent place in the illustrations and literature of early surveys, undertaken by the War Department,[1] and, from a scientific standpoint, are of great interest because they have been found to have adapted themselves to existence in regions of small rainfall in many remarkable ways. The numerous insects associated with cactus plants are naturally of great interest. These insects have adjusted themselves to the general conditions in the regions in which the plants grow and have also adapted themselves to the structure and habits of the plants themselves. Moreover, cactus insects have always held special interest on account of the cochineal insect. The cultivation of this species, which is indigenous to America, caused the prickly pear to be transported to remote parts of the globe, where it has been planted for the purpose of furnishing food for the dye-producing insect. The industry of rearing the cochineal insect was for years a very important one. It furnished valuable dyes which are still utilized for special purposes. In the Canary Islands alone, in 1876, the exportation of cochineal amounted to over 5,000,000 pounds. It has been determined that the bodies of about 70,000 cochineal insects are required to make a pound of the dried product. This gives an indication of the extent of the industry in the Canary Islands, which did not, however, produce nearly all of the supply which entered into commerce.

Except for the cochineal insect, the species feeding upon Opuntia have been until recently rather of scientific than of practical importance. In the early days, since it was necessary to cultivate the Opuntia plant as food for the cochineal insect, any species which injured the plant were of economic importance. In fact, the treatises on the cultivation of the cochineal contain directions about the control of various species which damaged the plant. With the decadence of the cochineal industry, the cactus plants became nuisances, except

[1] Pacific Railways Report, vol. 4, p. 37, 1856; U. S. and Mexican Boundary Survey, vol. 2, p. 35, 1859.

where the tunas were utilized as food.[1] They occupied land that could be used to advantage for valuable crops. In this way, in a few years, the plant was changed in character from a valuable one to a weed. Incident to this change the insects feeding upon Opuntia assumed an entirely different character. Instead of being considered pests, they came to be looked upon as beneficial on account of their destruction of the weed. In fact, in South Africa and Australia the encouragement of the insect enemies of prickly pear has been proposed as a feasible means of reducing the number of plants.

Within very recent years, at least in so far as the United States is concerned, there has been another revolution in regard to prickly pear. It has been recognized for many years in the southwestern portion of the United States that the plant furnished a supply of food for cattle during drought that frequently prevented the starvation of large herds. It was considered, however, that this was a rather poor return for the loss of large grazing areas on which the plants grew and which in normal seasons without the prickly pear would have furnished large amounts of forage. Some years ago Mr. David Griffiths, then of the Arizona Agricultural Experiment Station, began an investigation of the feeding value of prickly pear. It was soon found that the plant has a surprisingly high feeding value.[2] The greatest practical difficulty in the use of the plant for forage was the spines, but it was found to be possible to eliminate this difficulty by singeing the plants or by running them through machines which chopped them into small pieces. It was also discovered by Mr. Griffiths,[3] whose more recent work has been done as an agent of the Bureau of Plant Industry of this department, that when prickly pear is planted it responds readily to cultivation. In fact it was found that artificial plantings of the pear with only meager cultivation furnished a growth in three years that was fully as great as the growth under natural conditions in double that period. At this point, however, it became evident that the insects affecting the prickly pear would need to be taken into consideration. In fact it appeared in the experimental plantings of the Bureau of Plant Industry that the insect injury was one of the most important obstacles to the cultivation of the prickly pear as a farm crop. In this way there has been

[1] In this discussion we consider the prickly pear as a crop planted on a large scale but do not overlook the fact that its fruit has been utilized as food for man from very ancient times and is still an important human food in large areas. There has been no revolution as regards the tuna as food for man. It has always been important. However, the tunas are obtained from wild plants, or from those cultivated on a comparatively small scale about houses, and thus represent a system of growth quite different from the extensive field culture of the early days.

[2] The Prickly Pear and other Cacti as Food for Stock, by David Griffiths. (Bul. 74, Bur. Plant Ind., U. S. Dept. Agr., March 8, 1905.) Feeding Prickly Pear to Stock in Texas, by David Griffiths. (Bul. 91, Bur. Plant Ind., U. S. Dept. Agr., 1906.)

[3] Prickly Pear as a Farm Crop, by David Griffiths. (Bul. 124, Bur. Plant Ind., U. S. Dept. Agr., February 19, 1908.) The Tuna as Food for Man, by David Griffiths and R. F. Hare. (Bul. 116, Bur. Plant Ind., U. S. Dept. Agr., December 2, 1907.)

a complete revolution in so far as the importance of cactus insects is concerned.

## HISTORICAL STATEMENT REGARDING CACTUS INSECTS.

It has been stated in a preceding paragraph that the insect enemies of Opuntia attracted some attention in former years on account of their injury to the host plant of the cochineal insect. Several of the treatises on the cultivation of the cochineal contain brief suggestions about the destruction of the enemies of the plant, as well as about the enemies of the cochineal itself. In all these considerations, however, only the merest incidental attention was paid to species other than the cochineal.

The first systematic work on cactus insects that was undertaken was that done in 1895 by Mr. H. G. Hubbard, who lived in Florida. He discovered a lepidopterous larva, *Melitara prodenialis* Walk., which feeds upon the prickly pear, traced out its life history and transformations, and published a most interesting account of his observations.[1] A few years later Mr. Hubbard sojourned for some months in Arizona. In that territory he made studies of the insect fauna of the giant cactus (*Cereus giganteus*). Although plants of the genus Cereus will probably never be of importance as forage,[2] Mr. Hubbard's studies have a bearing upon insects infesting Opuntia, since the faunas of Cereus and Opuntia are largely the same. After his death, the results of Mr. Hubbard's investigations were published under the editorship of Mr. E. A. Schwarz.[3]

From 1896 to 1898, on various trips to the region then infested by the boll weevil, Mr. E. A. Schwarz made a number of observations on insects infesting Opuntia. In fact, he discovered a number of the species which have now been found to be of importance in the area in which the prickly pear is undergoing cultivation. Dr. L. O. Howard and Mr. C. L. Marlatt also made observations on cactus insects at about this time. The results of these incidental observations were published in notes in the Proceedings of the Entomological Society of Washington.

By 1905 Mr. David Griffiths had begun the cultivation of the prickly pear in the vicinity of San Antonio, Tex., and elsewhere. It was on his experimental plantings that the observation was made that the concentration of the plants under cultivation seemed to increase the amount of insect injury. Recognizing the importance of this matter, Mr. Griffiths immediately began the collection of specimens which, with full notes, were transmitted to the Bureau

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[1] Proc. Ent. Soc. Washington, vol. 3, pp. 129–132, two figs., 1895.

[2] The Cereus plants are, of course, utilized in many ways by the inhabitants of the region in which they occur, but not as forage.

[3] Psyche, May, 1899, Supplement, pp. 1–14.

of Entomology at Washington. This material was placed in the hands of Mr. E. S. G. Titus and Mr. F. D. Couden. In spite of the difficulties of rearing the specimens, due to the transportation to Washington and the utterly different climatic conditions, these entomologists succeeded in rearing a large number of specimens. This material, with the rearing notes and the field notes supplied by Mr. Griffiths, has been used in the preparation of this bulletin.

In 1907 Mr. Griffiths' field observations more than verified his previous impressions regarding the importance of cactus insects. By this time it had also become evident that the rearing work could be carried on to much better advantage in the regions where the Opuntia was grown and that field experiments in control were necessary. For these reasons, in 1907 the investigation was turned over to the branch of Southern Field Crop Insect Investigations. In connection with other work Mr. F. C. Pratt and Mr. J. D. Mitchell were detailed to institute an investigation of cactus insects in Texas. Mr. Pratt's work was continued with serious interruptions, due to his ill health, from late in 1907 until the fall of 1910. During this time he and Mr. Mitchell accumulated a very large amount of information about the insects associated with the Opuntia plant and regarding feasible means of control of the more injurious species. The original intention was that a publication on this subject should be prepared by Mr. Pratt. His ill health, which became acute about the time that sufficient material had been gathered to form the basis of a bulletin, and his death soon afterwards, prevented placing the matter in form for publication. This part of the work has been done by the senior author, who has also made some field observations, although the great majority of such observations were made personally by Mr. Pratt and Mr. Mitchell.

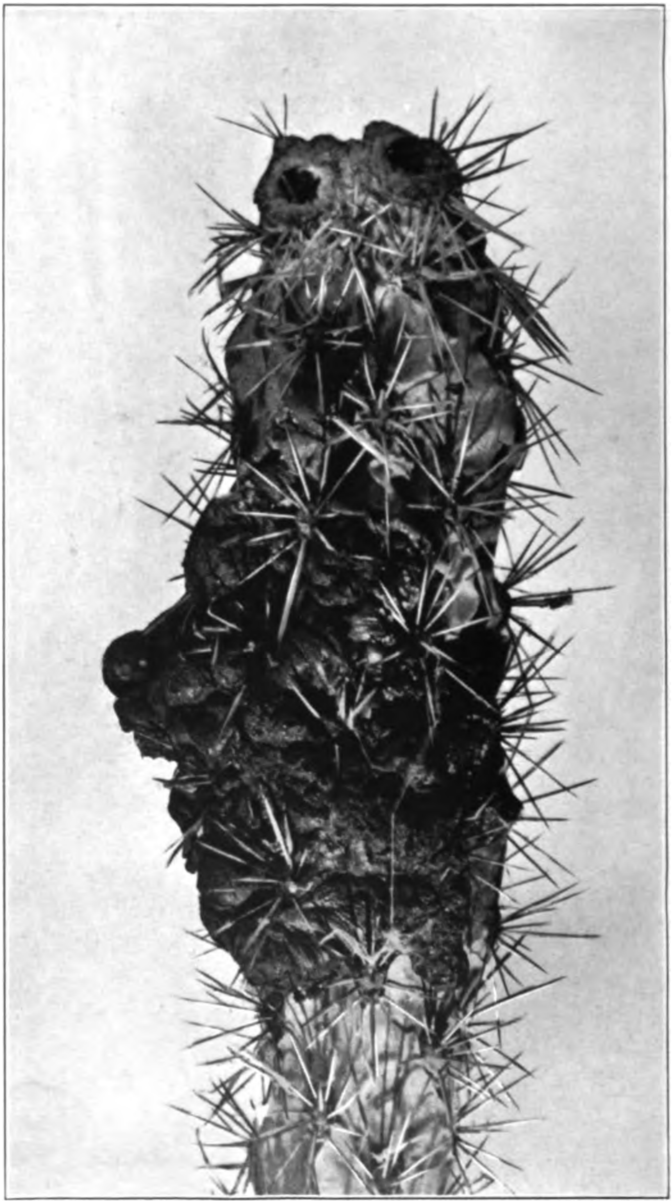
## NUMBER AND CLASSIFICATION OF CACTUS INSECTS.

As the result of the work we have done and that of the previous investigators who have been mentioned, 324 species of insects are known to be associated with the cactus plant. These divide themselves naturally into five categories, as follows: Species injuring the plant, 92; parasites of injurious species, 28; scavengers, 73; flower visitors, 40; species only incidentally associated with the plant, 91.

The injurious species affect different parts of the plant. In fact, no important part of the plant is immune from injury. Twelve species are known to attack the roots or stem. Twenty-seven species attack the joints, of which 11 species feed inside of the joints while 16 destroy the outer portion. A considerable number are found in the blooms; a few of these are injurious, but others undoubtedly assist in the fertilization of the plant. The fruit is injured by 13 species.

LONGICORN BEETLE, MONEILEMA CRASSUM, AN IMPORTANT ENEMY OF PRICKLY PEAR.

Adults feed on exterior of joints of the cactus, while the larvæ destroy the interior of both joints and stems. Enlarged. (Original.)



WORK OF LONGICORN BEETLE, MONEILEMA CRASSUM, ON THE CACTUS, ECHINOCEREUS SP. (ORIGINAL.)

The foregoing arrangement of five categories will be followed in the body of this bulletin. Within these categories the species will be treated in the order of their importance. In this place, however, we shall include a list of the principal species arranged as they rank in importance regardless of the parts of the plant affected.

## THE PRINCIPAL INSECTS INJURIOUS TO OPUNTIA IN ORDER OF THEIR IMPORTANCE.

1. Chelinidea, 3 species. Feeding upon the joints externally.
2. *Mimorista flavidissimalis* Grote. Attacking joints externally at first but later invading inner portion.
3. Narnia, 4 species. Feeding on joints externally.
4. Melitara, 4 species. Feeding within the joints.
5. Moneilema, 8 species. Feeding within joints and stems.
6. *Dactylopius confusus* Cockerell and *D. tomentosus* Lamarck. Feeding on surface of joints.
7. *Marmara opuntiella* Busck. Forming mines beneath surface of joints.
8. Asphondylia, 3 species. Feeding on interior of fruit.
9. *Stylopidea picta* Uhler. Feeding on surface of joints.
10. *Diaspis echinocacti cacti* Comstock. Feeding on surface of joints.
11. *Ozamia lucidalis* Walker. Infesting the fruit.
12. *Platynota rostrana* Walker. Feeding within the fruit.
13. Polistes, 3 species. Feeding on the fruit.

## INSECTS AFFECTING THE ROOTS OR STEMS.

### Species of the Genus Moneilema.

Among the insects which affect the roots or stems the most important forms are eight species of the cerambycid genus Moneilema, to which the common name "Opuntia longicorns" may be applied. These are wingless, robust, shining black beetles,[1] from about 15 to 25 mm. in length. (See Pl. I.) They are to be found upon the Opuntia plants as adults throughout the season. In the adult stage they do considerable injury by gnawing the edges of the newly formed joints. This injury, however, is insignificant in comparison with that done to the stems and roots by the larvæ.

The most important species of Moneilema in Texas are *M. crassum* Le Conte and *M. ulkei* Horn. These are widely distributed in the State. Other species are included in the list at the end of this bulletin.

It is interesting to note that the work of the adult beetle sometimes results in the dissemination of the plant. Frequently the beetles cut

[1] One species, *ulkei*, is opaque, its surface mottled with whitish.

at the base of a newly-formed joint, so that it is soon broken from the plant. In some cases the joints thus separated from the plants take root upon falling to the ground. As a matter of fact this accidental planting by the Moneilema beetles is one important cause for the growth of the prickly pear in very dense clusters around the old plant.

### DESCRIPTION OF THE LARVA OF MONEILEMA CRASSUM.[1]

About 12 mm. long when full grown. Body white, with a dark-brown chitinous head and with a pale-yellow semichitinous prothoracic area. Head transverse, rounded oblong, with the labrum, sometimes the labium, and the maxillæ light yellow in contrast to the dark-brown mandibles and occiput. Eyes obscured. Antennæ single jointed, very small, placed immediately behind the mandibles. Labrum and clypeus transverse; mandibles large, apically emarginate, distant; maxillary and labial palpi small. Body sparsely covered with brown setæ. Prothorax tumid, twice as large as either mesothorax or metathorax. Mesothoracic spiracles plain. Abdomen 10-segmented, the last 2 modified, forming the anal region; first 8 segments provided with large, round spiracles; first 6 dorsally prominently bituberculate; first 7 ventrally transversely grooved.

These larvæ infest the main stem and older joints of the prickly pear. The gallery is wide and soon becomes blackened. The frass frequently becomes infested with dipterous larvæ of various species. The larvæ are capable of considerable movement and have been found frequently to travel from one part of the plant to another in order to obtain a better supply of food. After attack the plant appears sickly and shows copious exudations of black sap which becomes so hard that it can be cut with a knife with great difficulty. The appearance of this black exudation is shown in an accompanying illustration (Pl. II).

The larva makes an imperfect cocoon, in which transformation to the pupa takes places. These cocoons consist of an inner layer of fiber of the cactus plant covered with sand. The texture is very firm. They measure 25 by 35 mm. They are generally found just beneath the prostrate joints on the ground. The duration of the immature stages was not determined, but it is evident that there is only one generation during the season. Adults appear most commonly in April and May and in September.

As the Moneilema beetles are among the more important insects of the prickly pear, it may be necessary to combat them in plantings. Three means of attack are in evidence from the account that has just been given, namely, burning, hand picking, and poisoning. The larvæ and cocoons can be destroyed by burning the prostrate portions of the plants. The injury can always be located by reason of the large number of joints and stems that have fallen to the ground. A

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[1] Prepared by Mr. W. D. Pierce.

little work in raking together and burning the fallen portions of the plant where they are numerous would serve to hold the insect in check. If this practice has not been followed, it will still be possible to check injury with some satisfaction either by poisoning the adults or by collecting them by hand. On account of their large size and sluggish movements and the fact that they are without wings, hand collecting is not difficult and will be very effective. This process would generally be preferred to that of poisoning on account of its cheapness. When poisoning is practiced, arsenate of lead should be used. It should be applied, in powdered form only, to the young and tender joints, as the adults feed upon no other parts of the plant. The poisoning of these young joints will also serve to control at least one other important enemy of Opuntia, as will be described later.

### A Cutworm.

On several occasions a cutworm, *Chorizagrotis soror* Smith, has been found to do considerable injury to Opuntia plants. The damage is greatest in the case of young plantings. The pulp that is exposed in cutting the joints into suitable pieces for planting seems to attract these worms. In one of the plantings at San Antonio, Tex., they ate canals through the underground portions of the plants. They are partial to the varieties of more tender structure. Whenever this insect is abundant it will be easy to protect the plants by soaking the portions used for seed for a few minutes in a solution of arsenate of lead, or, if more convenient, the sections to be planted could be dusted with the powdered arsenate of lead at the time of planting.

### Coccidæ

The only other insects which have been found attacking the roots of Opuntia plants are three species of Coccidæ, or scale insects. None of these species has been found to be abundant or to have any marked effect upon the vigor of the plant in the localities in which they occur. It is consequently unnecessary to give them further attention.

## SPECIES ATTACKING THE JOINTS EXTERNALLY.

### Chelinidea vittigera Uhler.[1]

The coreid bug, *Chelinidea vittigera* Uhler, may be readily recognized from the following brief summary of its appearance and habits:

It is a yellowish bug resembling the common squash bug (*Anasa tristis* De Geer) in general appearance (fig. 1), about 15 mm. long,

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[1] Order Hemiptera, Family Coreidæ.

feeding generally gregariously on the joints of Opuntia and allied genera. It is chiefly nocturnal in its habits. The first indications of feeding are the occurrence of lighter circular spots on the joints. The whitish excrement of the insect, which covers the surface of the joint, is also conspicuous. During the winter the insects are to be found in large numbers in a somewhat dormant condition under prostrate joints.

This species and its congeners are restricted to cactus plants and are by far the most important Opuntia insects occurring in the United States. On account of the wide distribution and prolific breeding of *C. vittigera* it is conspicuous in all localities where it occurs. Within its range *Mimorista flavidissimalis* Grote is probably more destructive to the plants, but that species is restricted to a comparatively small portion of the area occupied by Opuntia.

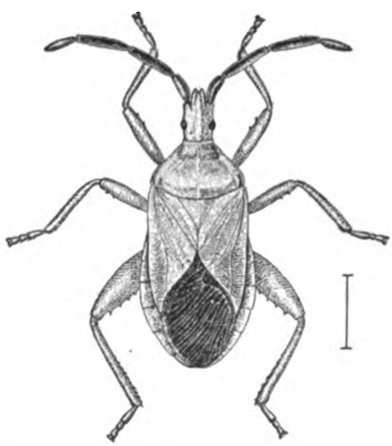

FIG. 1.—A cactus insect, *Chelinidea vittigera*: Adult. Enlarged. (Original.)

NATURE OF INJURY.

The small circular discolorations on the joints resulting from the work of this insect do not appear until feeding has progressed for some time. As soon as they do make their appearance, however, they are extremely conspicuous. They may be found upon only a few joints of a plant, or where the bugs are more abundant all the joints may be affected. As the injury proceeds, the spots become larger and coalesce, so that the whole area of the epidermis assumes a deadened, yellowish, and pitted appearance. The whitish excrement is discharged more profusely when the bugs are approached and may possibly have some protective effect.

As a result of attack the plant is weakened so that it soon falls over. Where the bugs are numerous the fallen plants give somewhat the same appearance as they would if battered down by heavy hail. In some cases, where the attack is not strong, portions of the fallen joints take root and give rise to new plants. More frequently, however, the joints are unable to recuperate and either dry up completely or become the breeding places for the many species of scavenger insects found associated with the cactus plant.

As soon as the bugs, whether in the nymphal or adult stages, have weakened a plant they migrate to other plants and continue the work of destruction.

It has been observed by Mr. J. D. Mitchell that the joints upon which the bugs have fed, and which may not have shown any special damage during the season, are the ones first injured by frosts during the following winter. This indirect injury sometimes results in setting the plants back by as much as the growth of two years. Another form of injury which is suspected but not proven in the case of this bug is the dissemination of the fungous disease *Perisporium* sp. This disease causes large black spots on the joints. The infected area frequently drops out, leaving a more or less circular opening through the joint. The feeding habits of the bug are such as to render it very likely to plant the spores of the fungus when it travels from one joint to another.

This species was first called to attention as an enemy of Opuntia by Mr. F. W. Thurow, who, in March, 1893, reported to the Department of Agriculture that three species of Opuntia growing in Harris County, Tex., were greatly damaged.[1]

### DISTRIBUTION.

This species is not confined to the prickly-pear region proper, although there is no doubt that it greatly prefers that plant and that it is much more abundant where the Opuntia occurs in large numbers. Its western limit in Texas, so far as ascertained, is Brewster County. In the east it occurs along the Gulf and inland as far as Trinity County, Tex. It has been taken in Dallas and Parker Counties, Tex., wherever Opuntia occurs. It has also been observed in California, Utah, and Colorado, and in fact is generally distributed throughout the Western and Southern States. In the East it is found in Louisiana, Alabama, and North Carolina and has been recorded from Virginia.

### VARIATIONS.

The following notes on variations in *Chelinidea vittigera* have been furnished by Mr. O. Heidemann, who examined all of the hemipterous insects taken on cactus:

> The species is exceedingly variable in structure of the body and in color. The relative length of the head, described by Prof. Uhler as being two-thirds the length of the thorax, can hardly be considered as a constant character. There are specimens which have the head and thorax subequal in length or equal. The peculiar prism-shaped antennal joints are more or less dilated, in some examples very conspicuously. This variation in the dilatation of the antennal joints is noticeable even in those specimens marked as reared from Opuntia. The color of the antennæ, elytra, and legs varies considerably, changing from reddish-brown into black. The darkest, most developed forms occur in Colorado and Utah.

[1] Insect Life, vol. 5, p. 345.

## LIFE HISTORY, AND DESCRIPTION OF STAGES.

The oreeding of this insect in the cactus area begins early in the season. At San Diego, Tex., in March, Mr. J. D. Mitchell observed that the first brood had appeared. In April the first young were noticed in Victoria County. The bugs breed continuously throughout the summer and fall. Owing to the fact that certain individuals are retarded in their development no definite number of broods is determinable. It has frequently been observed that some specimens reach the adult stage before others from the same mass of eggs have passed the third nymphal stage. This explains the observation of many persons that the bugs can be found in all stages on the plants at all times except during cold weather.

The eggs are deposited generally on the spines, although in confinement the females deposit on the sides of rearing cages and in some instances eggs have been observed on the sides of dead as well as of living joints. The spines, however, are undoubtedly the normal place for deposition of the eggs. (See Pl. VII, fig. 2.) During the summer season 5 adults produced 198 eggs in 15 days, averaging practically 40 to the individual. These females were not reared, so that it is more than likely that the capacity for egg laying is much larger than the figures would indicate. The method of oviposition was observed by Mr. C. E. Hood. He noted that the female begins by rubbing the spines or surface on which the eggs are to be laid with the tip of the abdomen, probably discharging a sticky substance. After the egg is about halfway protruded a circular motion of the abdomen is observed. The female then appears to rub the egg over the spine before finally discharging it. In this manner 4 eggs were deposited in 6 minutes. It was observed in the breeding cages, and frequently in the field, that the eggs are not securely fastened to the spines. The attachment is so weak that they fall as the result of even a slight disturbance.

### THE EGG.

Length, 1.25 mm.; width, 0.75 mm. Dark brown, opaque, very finely and uniformly punctured, mottled with a whitish exudation. Elliptical; lid subdorsal, large elliptical. Placed with great regularity about 0.5 mm. apart on spines, with longitudinal axis parallel to spine, each string of eggs from 6 to 25 mm. in length. Duration of egg period, from 12 to 20 days.

### THE NYMPHAL STAGES.

*First instar.*—Length, 2 mm. Brownish black, except abdomen, which is pea-green in some individuals and a dark crimson in others. The former variety shows a slightly red callosity and margins. Antennæ 4-jointed; club short; first joint slightly flabellate; second joint scarcely one-third longer than the third; first and second joints with apical tips terminating in short spine. Head produced, bifurcate. Length of stage, 7 days.

*Second instar.*—Length, 4 mm. Very little change from first instar except that the femora and prothorax have a slightly lighter color. Second joint of antenna with almost straight sides. Spines on first and second joints more pronounced. Length of stage, 4 days.

*Third instar.*—Length, 5.5 mm. Spines on first and second antennal joints slightly more pronounced, as is the raised callosity on the abdomen. The two transverse brown slits very conspicuous. Prothorax changing to greenish. Antennæ more distinctly flabellate; otherwise there is little change. Length of stage, 4 days.

*Fourth instar.*—Length, 6.5 mm. Greenish color on abdomen decidedly darker; legs, antennæ, head, and thoracic spines olivaceous black. No change in spines. Length of stage, 12 days.

*Fifth instar.*—Length, 7.5 mm. The abbreviated wing-pads appear and extend over the two anterior abdominal segments. General color dull olivaceous black, except tips of antennæ, which are orange. Prothorax considerably wider, thus altering the appearance greatly, as the previous stages have a very narrow prothorax in comparison to the abdomen. Length of stage, 14 days.

The duration of the fourth and fifth instars was determined during October; that of the earlier stages in July and August. Undoubtedly the duration of the last stages in summer does not greatly exceed that of the earlier ones.

### DIMORPHISM.

In the examination of several thousand of these bugs which have been under observation in the field and in rearing cages it was noticed that there was a great variation in the color of the adults from different localities. This variation is much more noticeable in the nymphal stages. The color of the abdomen is either pea-green or dark crimson. Repeatedly experiments in breeding these color variations resulted in rearing adults which could not be distinguished.

### HIBERNATION.

At a temperature from 45° to 50° F. these bugs appear to be restless, congregating at times, and at other times dispersing in order to find suitable quarters for hibernation. Throughout the winter they are to be found in numbers under fallen cactus joints, in the trash that accumulates at the base of the plants, under grass roots, and in fact wherever they can obtain shelter in the immediate vicinity of the Opuntia. They do not seem to travel any considerable distances from the plant upon which they were produced.

### Chelinidea tabulata Westwood

The species *Chelinidea tabulata* Westwood has often been observed in company with *Chelinidea vittigera*. It is not common, but if it were it would easily rank as a pest of prime importance on Opuntia. It is a Mexican species hitherto not known to occur in the United States. In our collections it has been taken at many localities from Austin, Tex., southward and westward.

### Chelinidea sp.

A third species of the genus Chelinidea was taken in May at Tuscon, Ariz., on *Opuntia arbuscula*, *O. versicolor*, and *O. fulgida*. This species is somewhat smaller than the preceding. Rearing experiments were unsuccessful on account of the shipment of the species into a region of different climate.

### The Control of Chelinidea vittigera and Allied Species.

Two features of the life history of these bugs reveal feasible means of control. These are the clustering of the adults during winter and the gregarious habits of the young. The best control practice to follow is undoubtedly to collect and burn the trash on which the insects are found during the winter. At that time they are almost completely dormant and can be raked into piles along with the débris and burned. The gregarious habit, which is especially well marked in the earlier immature stages, makes it easy to check the development in a different way. The use of the gasoline torch, which is found upon all plantations where the cactus is used for forage, gives an economical and effective method of destroying these stages. Whenever the appearance of the small circular spot and of the white excrement shows that the insects are beginning to injure the plants seriously, the torch can be brought into play to excellent advantage.

### Mimorista flavidissimalis Grote.[1]

The cactus insect *Mimorista flavidissimalis* Grote may be recognized easily from the following description:

From one to seven yellowish larvæ feeding invariably on upper edge of young joints of Opuntia under a silken web, sometimes penetrating the interior. (Pl. III.)

After the Chelinidea bugs, this insect is the most important enemy of Opuntia in the United States. Unlike the Chelinideas, however, it is restricted in its range. In Texas it is found from Hallettsville and San Antonio southward. West of San Antonio it is rare, but was taken at Tucson, Ariz., in May by Mr. Pratt. In the area where it is common it is by far the most injurious cactus insect.

The species was described by Grote in 1877 from specimens received from Texas. Since then it has not been recorded outside of Texas. It was not until 1905, when the present work was undertaken, that anything was known about the early stages. The first rearings were made at Washington, D. C., from material collected at San Antonio, Tex., by Mr. David Griffiths.

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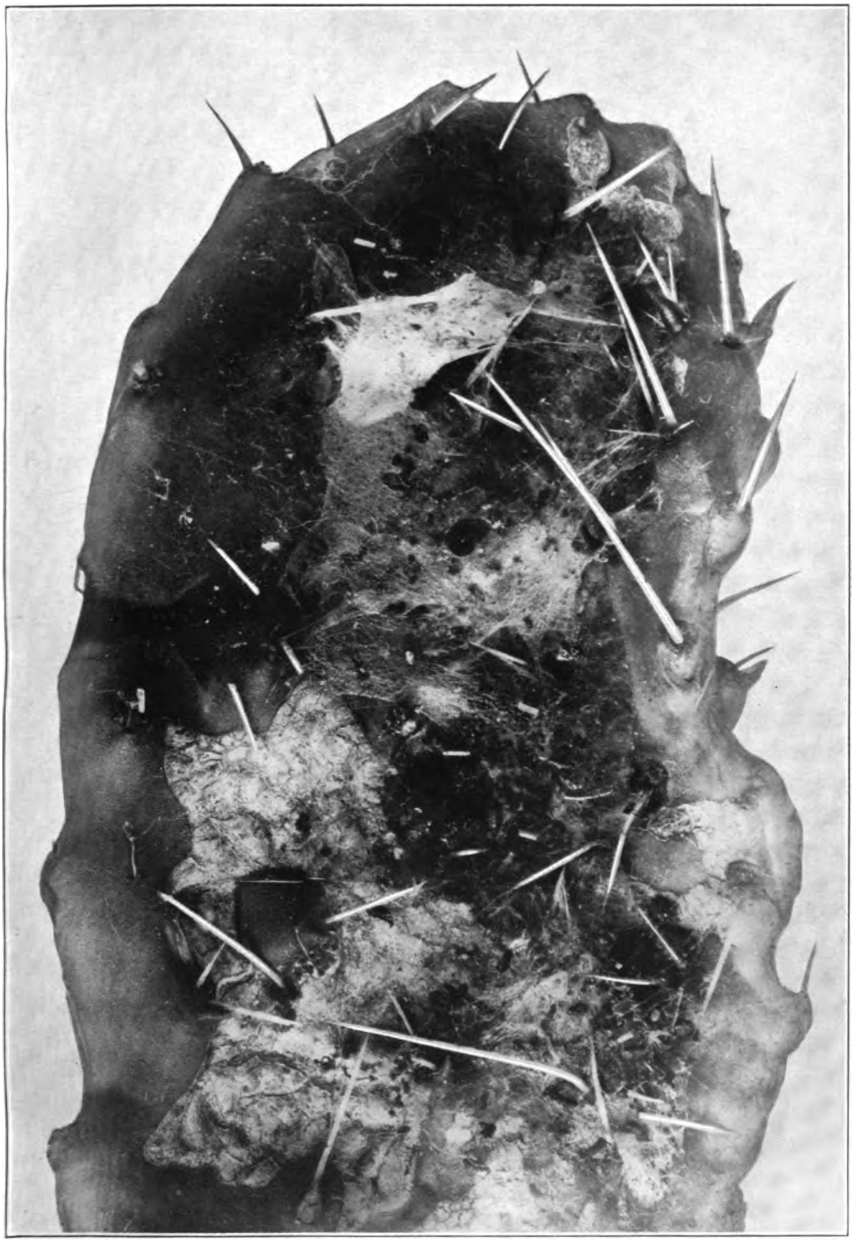
[1] Order Lepidoptera, family Pyralidæ.



WORK OF MOTH, MIMORISTA FLAVIDISSIMALIS, ON JOINT OF OPUNTIA. (ORIGINAL.)

LARVÆ OF BEETLE, DISONYCHA VARICORNIS, ON OPUNTIA LEPTOCAULIS.
(ORIGINAL.)

### THE ADULT.

The adult is a moth which expands about 1 inch. It is bright straw colored, with inconspicuous brownish markings arranged in four irregular transverse bands.

### THE LARVA.

Length, 11 mm.; shining; general color yellowish white; legs concolorous; head and cervical shield somewhat darker yellow. Sides parallel, except for slightly raised spiracular callosities; faintly impressed median line. Two minute spots on cervical shield and spiracles black. Hairs long, sparse; most numerous on first six segments; white in color; arranged in subdorsal, marginal, and submarginal series; none on median line.

### THE PUPA.

Inclosed in a whitish cocoon of thin, dense, paper-like construction; length, 9 mm.; width, 3 mm.; shining, light brown; head black. On thoracic segment one median and eight lateral fine longitudinal dark lines; the ones on either side of the median line are double for a short distance near their anterior third.

### SEASONAL HISTORY.

A generation of this species is produced in about 30 days. The earliest record of the rearing was made by Mr. J. D. Mitchell on May 29 at Victoria, Tex. In that locality the second generation of the year had developed by June 26. The fifth generation matured by September 15. In all probability there is one additional brood during the season in southern Texas.

### DAMAGE.

The injury by this species is confined to the young joints. Mr. Mitchell has repeatedly seen from 50 to 75 per cent of the new growth destroyed over considerable areas. The moth deposits from one to seven eggs, always on the upper edge of the joint. The first indications of injury are strings of sap exuding from the joints. If this discharge is removed a small hole becomes visible. As the larvæ develop the discharge of sap from the plants becomes mixed with silk, trash, and excrement discharged by the insects. (Pl. III.) In rare cases, when only a few eggs have been deposited, the joint recovers, although it is always deformed. In most instances, however, decay begins, and the joint turns black and finally drops to the ground.

The two features of the attack of this insect which cause it to be of great importance in connection with the cultivation of cactus are, first, the large number of broods occurring throughout the season, and, second, the attack against the new growth. Where the species is at all abundant this attack effectually prevents any additional

growth of the plants. At the end of the season there are no more joints than there were the year before.

A hymenopterous parasite of this species, *Eiphosoma texana* Cresson, has been reared. It does not appear, however, to be sufficiently abundant to exert much control over the species.

### CONTROL.

Mr. J. D. Mitchell has found by experiments performed at Victoria, Tex., that it is not difficult to control the species by the early application of powdered arsenate of lead. As soon as damage becomes evident in the spring the new growth should be dusted carefully with this arsenical. In this way the majority of the first brood will be destroyed. Some of the joints infested at that time will recover and there will be little injury from the following broods. The early application of the arsenical is very important on account of the formation of the protective web soon after the larvæ have begun work. If the first brood should not be reached in time every effort should be made toward applying the poison in ample time for the second brood.

In the case of small experimental plantings the use of the gasoline torch will furnish an economical means of control. In other cases the cutting off and burning of the early infested joints will answer the same purpose.

### Disonycha varicornis Horn.[1]

*Disonycha varicornis* Horn is a flea-beetle about 7 mm. in length. It is of conspicuous appearance on account of the brilliant polished blue of the elytra. The head and thorax are yellow; the under parts dark brown. So far as known this insect is restricted to *Opuntia leptocaulis* and *Opuntia arborescens*. It has never been found on the broad-leafed species of the genus Opuntia. It is observed frequently on its host plants in the adult and immature stages. The larvæ feed on the surface of the plants without any protective covering whatever. (Pl. IV.) Frequently they occur in such numbers as to cause the death of the plants. As it happens that the cacti attacked by this insect are not of any special economic importance, it is unnecessary to give further attention to the species.

### Stylopidea picta Uhler.[2]

*Stylopidea picta* Uhler is a slender hemipterous insect about 6.5 mm. long. The head and thorax are bright crimson and the wing covers slate color but with narrow yellowish borders. The eyes are

[1] Order Coleoptera, Family Chrysomelidæ, Subfamily Halticinæ.
[2] Order Hemiptera, Family Capsidæ.

placed at the end of the stalk-like prolongations of the head. The under parts are dark brownish.

The species has been collected on Opuntia from San Antonio, Tex., to the coast and southward to Brownsville, Tex. It seems to be more abundant in the vicinity of Corpus Christi, Tex., than elsewhere. The injury is not conspicuous. It causes the plants to assume a spotted appearance, but, except where the bugs are unusually abundant, the joints recover. It is not a true cactus insect, but has been found upon a variety of other plants. On account of its gregarious habits it could be easily controlled by means of the gasoline torch when it becomes unusually abundant.

### The Cottony Cochineal Insect.[1]

(*Dactylopius confusus* Cockerell.)

The cottony cochineal insect (*Dactylopius confusus* Cockerell) is easily recognized by the large flocculent masses of pure white wax which covers the bodies. (Pl. V, upper figure.) When crushed the bright crimson color of the body fluid runs out and contrasts strongly with the white envelope. These scale insects are found on the joints of Opuntia, frequently in large masses.

This species is closely allied to the true cochineal insect, *Dactylopius coccus* Costa, which does not appear to occur in the United States.[2] The true cochineal has only a light powdery covering, while the form in the United States is provided with the heavy covering of cottony wax which has been described.

The true cochineal insect has had a most interesting history. Carried to many parts of the world and cultivated with extreme care, for many years the dried bodies of the females yielded a dye product of great importance in the commercial world. It was also supposed to be an important therapeutic agent.

In A. von Humboldt's Political History of the Kingdom of New Spain, published in 1811, there is a most interesting account of the cochineal industry in southern Mexico. The author relates that there was every indication that the cultivation of the insect had been practiced for many centuries, undoubtedly, even antedating the invasion of the Toltec tribes. During the reign of the Aztec kings the industry was apparently much more important than at the time of Humboldt's observations. As early as 1592 laws were passed to prevent the adulteration of the product. In 1802 the exports through the port of Vera Cruz amounted to 3,368,557 pounds.

The greatest development of the cochineal industry occurred about 1876. The decline began at that time on account of the discovery

[1] Order Hemiptera, Family Coccidæ.

[2] The records from Florida and California in the Fernald Catalogue are probably due to importations.

of aniline dyes. For several years the commercial cochineal crop of the world amounted to more than 7,000,000 pounds. Although the amount produced now is very much smaller, it seems to be more or less constant. In 1909, the last year for which statistics are available, the United States imported 102,000 pounds of a value of $33,875. Practically all of this supply is obtained, either directly or indirectly, from the Canary Islands. The average annual importation into the United States for seven years ending with 1909 was 130,000 pounds.

Cochineal is now used as a coloring matter for fine fabrics, certain kinds of ink, and confectionery. It is also used as a coloring medium for solutions and emulsions, being found practically in every drug store in the country. For many years it was used more or less regularly as an anodyne, but this use has been largely discontinued.

The cottony cochineal insect occurs practically throughout the cactus region in the United States. It has been found to be abundant as far north as Young County, Tex. It is attacked by a large number of predaceous insects. These tend greatly to hold the cochineal insect in check. Otherwise it would be a pest of prime importance on Opuntia plantations. As it is, it not infrequently becomes so abundant as to destroy portions of the plants and, on occasions, even as far north as central Texas, it has been found that entire plants have been destroyed.

### ENEMIES.

The insect enemies of the cottony cochineal insect, so far as known, consist of eight species of Coleoptera and three of Lepidoptera, as follows:

#### COLEOPTERA.

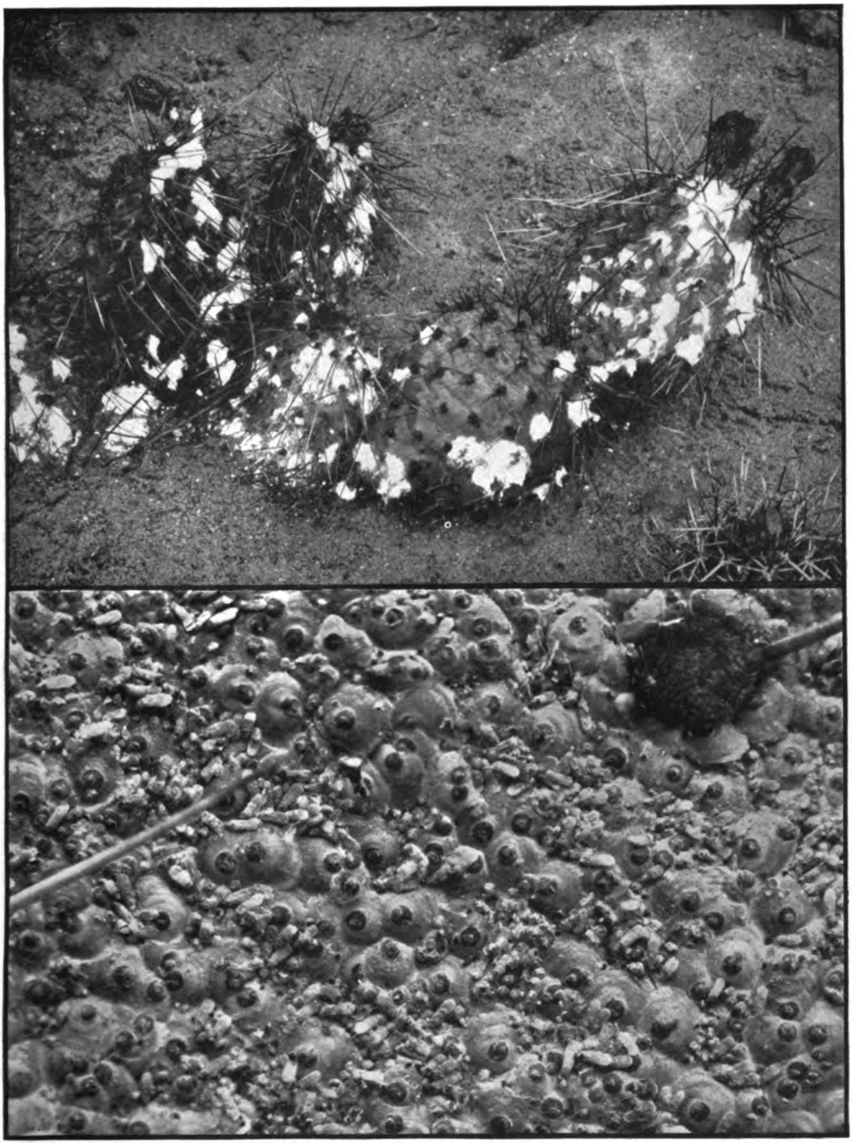
*Exochomus latiusculus* Casey; *Exochomus marginipennis* Le Conte; *Cycloneda munda* Say; *Chilocorus cacti* Linnæus; *Hyperaspis trifurcata* Schaeffer; *Hyperaspis cruenta* Le Conte; *Scymnus loewii* Mulsant; *Scymnus hornii* Gorham.

#### LEPIDOPTERA.

*Lætilia coccidivora* Comstock; *Zophodia dilatifasciella* Ragonot; *Saluria ardiferella* Hulst.

### CONTROL.

Attention has been called to the fact that in the United States the insect enemies of the cottony cochineal insect prevent its reaching great numbers until the middle of summer. In artificial plantings at times it may be necessary to resort to remedial work. In such cases the best plan to follow will be to remove the masses on the joints by means of a very stiff brush or to burn them with a torch. In some cases spraying with kerosene emulsion or the lime-sulphur mixture might be followed, but the extensive secretion of the insect will interfere greatly with the application of any insecticides.



TWO IMPORTANT SCALE INSECTS OF PRICKLY PEAR.

Upper figure, the cottony cochineal insect, *Dactylopius confusus;* lower figure, *Diaspis echinocacti cacti.* Lower figure enlarged. (Original.)

In hothouses the use of a solution of whale-oil soap or of tobacco stems is recommended for this and other scale insects of cacti. Any preparation that may be used should be applied with considerable force by means of a spray pump in order to reach the insects in the crevices of the plants.

### Minor Species Attacking the Joints Externally.

In addition to the species described in the preceding pages a considerable number of forms have been found which occasionally feed upon the joints. None of the other forms is at present known to be of any great economic importance, although they are likely to become abundant and injure the plants under local conditions at any time. The species more likely to do so are mentioned in the following paragraph.

*Diaspis echinocacti cacti* Comstock is a grayish scale insect, the females circular and the males oblong. It sometimes becomes so numerous as to cover entirely the surface of the joint. This condition is shown in an accompanying illustration. (Pl. V, lower figure.) In artificial plantings and in hothouses this species is of some importance. Under field conditions it rarely reaches excessive numbers. *Dactylopius tomentosus* Lamarck, which resembles the cottony cochineal insect but differs from that species by the fact that the separate individuals, instead of masses of several individuals, are covered by the cottony secretion, may be destroyed by the means recommended for the cottony cochineal insect. The white ant *Termes flavipes* Kollar feeds upon a great variety of cactus plants and has been observed to injure the joints thrown on the ground for growing a new crop. It sometimes constructs nests in the damaged joints. The scale insect *Eriococcus coccineus* Cockerell has been recorded from California. *Aphis medicaginis* Koch, a plant louse, apparently passes the winter on Opuntia in Texas. During the remainder of the year it is seldom found on Opuntia plants, and on the whole causes only very slight injury.

## SPECIES ATTACKING THE JOINTS INTERNALLY.

### Melitara junctolineella Hulst.[1]

*Melitara junctolineella* Hulst and the other species of the genus are true cactus insects. They may be recognized from the following brief description: Large indigo-blue (young) or conspicuously banded (last stage) larvæ living within the joints of Opuntia, cause large excavations and tumor-like swellings of the infested joints. The adult is a grayish moth of an expanse of 1½ inches.

The eggs of this species are very similar to those of *Melitara prodenialis* Walk. which are described on another page. They are deposited in exactly the same manner. The remarkable arrangement

[1] Order Lepidoptera, family Pyralidæ.

is shown in one of the accompanying photographs. (Pl. VII, fig. 1.) The individual egg masses may contain as many as 30 eggs.

There seems to be only one brood each year. As soon as the larvæ hatch in the spring they begin feeding upon the surface of the joint. Within a few days they make their way to the inside and never appear upon the surface. The experience of all observers is that only one or two larvæ are ever found within a joint. This is remarkable in view of the fact that the eggs are deposited in such numbers. Apparently it is not a case of the young larvæ traveling from one joint to another, since frequently only one or two joints on a plant are found to be infested. Undoubtedly the larvæ are cannibalistic in habits, and this accounts partly for the fact that these isolated individuals are found; but there is also another factor to be considered. The work of the larvæ immediately causes a strong reaction on the part of the plant. A copious secretion of proliferous tissue is formed and larvæ have been frequently found completely engulfed in this formation. Undoubtedly the pressure frequently results in the destruction of the larvæ.

Although this species is an internal feeder, the indications of its work are more or less conspicuous. The joint soon takes on a yellowish appearance and the large swellings on both sides of the joints are common sights in the cactus country. The entire interior is destroyed and the proliferous growth causes the swellings which frequently result in the increase in the thickness of a joint by three or four fold. Strangely such swollen joints are sometimes found to contain no larvæ. The evidence of their work is always present. Pressure from the proliferous growth may have caused the death of the larvæ in such cases.

The effect upon the plant is generally to cause the death of the joint or joints which are infested. The injury is made greater by a number of scavengers, principally dipterous. As the larvæ frequently make their way through the stem from one joint to another, it is not uncommon for several joints to be killed outright. Of course the portion of the plant above the infested joints dies from lack of nutrition. After a time the wind causes the diseased branch to fall to the ground. In case the larvæ are killed by pressure the swelling subsides. The sides, however, do not unite and the joint remains deformed. Mr. J. D. Mitchell, who has made many careful observations on this species, believes that the partial healing of the injury follows when the exit is at the lowest part of the stem, and that the joint falls invariably when the exit is near the top and the softened excrement and proliferous tissue can not escape.

Although this insect is not extremely abundant in any locality where observations have been made, it is to be found throughout the cactus area. In some localities at least one plant in every clump has

some portion infested. The total damage done is consequently considerable.

### DIVERSITY OF HABITS.

All of the Melitaras reared from cactus during the course of this investigation have been identified by Dr. H. G. Dyar as *Melitara junctolineella* Hulst. However, certain peculiarities in habits have been observed which lead to the suspicion that more than one form may occur. In the region south and east of San Antonio, Tex., the only form occurring makes no opening through the surface of the joint, but packs its excrement in the cavity made in the process of feeding. This form spins a cocoon on the joint or on the ground in case the joint has fallen, but this cocoon is not intermixed with sand or dirt. In the region from Kerrville, Tex., westward, a form occurs which invariably provides an orifice in the joint of the Opuntia through which the excrement is dropped to the ground. This gives a characteristic appearance of the joint which is easily recognized at a considerable distance. This form seems invariably to enter the soil for pupation, and a considerable amount of sand is intermixed with the cocoon spun for the protection of the pupa.

### DESCRIPTION OF IMMATURE STAGES.

#### THE LARVA.[1]

Early stages whitish; subsequent stages up to the last deep indigo-blue; last stage, 30 to 50 mm. long, conspicuously banded. These bands are dark brown and occupy the posterior quarter of each segment. Head 2.5 mm. wide, dark brown; clypeus rather deeply emarginate, with light colored band at base. Anal plate almost semicircular in outline, yellow; feet yellow, crochets in ellipses; skin plainly wrinkled on dark annulations, less wrinkled on lighter portions; spiracles elliptical, one and one-half times as long as broad, deep black; thoracic legs light brown; hair very sparse, light yellowish, confined to head, sides, and underside.

#### THE PUPA.

Incased in loose silken cocoon, sometimes intermixed with sand. 25 mm. long by 9 mm. wide, uniform mahogany brown, spiracles darker; head and thorax transversely rugose; anterior portion of abdominal segments very finely punctured; posterior portions more sparsely punctured and slightly wrinkled.

### PARASITE.

A tachinid parasite of this species, *Phorocera comstocki* Williston, is common. It has been reared from material collected throughout the cactus area.

### CONTROL.

The process of singeing the spines of prickly pear preparatory to feeding undoubtedly destroys many of the eggs of this species. In

[1] The larva described by Dr. Dyar as probably that of *M. junctolineella* (Proc. U. S. Nat. Mus., vol. 25, p. 396) evidently belongs to some other species.

experimental plantings the use of the gasoline torch in the spring and the burning of the joints that appear injured will keep the species in check.

**Melitara dentata Grote.**

*Melitara dentata* was described by Grote in 1876 from Colorado. In 1892 Prof. V. L. Kellogg published an account[1] of the transformations of the species in the leaves of *Opuntia missouriensis* taken in eastern Colorado. All stages were described and illustrated. The occurrence of blue and white larvæ, which we have observed frequently in the case of *Melitara junctolineella*, was noted by Prof. Kellogg.

The same species was collected by Mr. David Griffiths in Trinidad, Colo., in June, 1906. From this material a large number of parasites, *Chelonus laticinctus* Cresson (fig. 2), were reared.

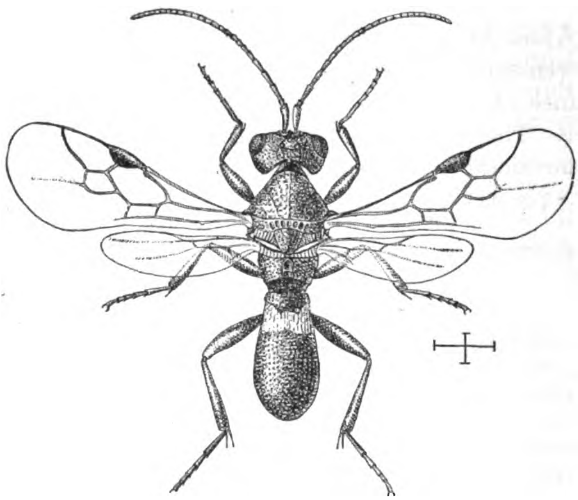


Fig. 2.—*Chelonus laticinctus*, a parasite of a cactus insect, *Melitara dentata*: Adult. Enlarged. (Original.)

**Melitara prodenialis Walker.**

The species *Melitara prodenialis* of Walker was described in 1863. In 1877 Miss Mary Treat sent cocoons from *Opuntia polyantha* collected at Green Cove Springs, Fla., to the Bureau of Entomology. In 1895 Mr. H. G. Hubbard published an interesting account of the oviposition of the species on *Opuntia vulgaris* at Crescent City, Fla., and also included an account of the habits of the larvæ. Previously Dr. J. B. Smith[2] had described briefly the method of placing the eggs on the plant. These few records constitute all that has ever been published concerning the species.

The notes on oviposition of this species and the habits of the larvæ, made by Mr. H. G. Hubbard, are as follows:

The eggs are laid at night, and the operation of depositing them has not been observed. It must, however, be a wonderfully interesting performance. The egg-stick * * * is 80 mm. long. The separate eggs are cylindrical and

[1] Kans. Univ. Quarterly, vol. 1, pp. 39–41.
[2] Entomological News, vol. 3, p. 208, 1892.

measure 2 mm. in length by 7 mm. in width. The surface is beautifully reticulated with wavy raised lines anastomosing obliquely. The eggs are cemented together with a brownish glue which, under the pressure exerted upon the mass, is squeezed out at the sutures between each two eggs in the stick and hardens there, forming a ring or collar which always adheres to the egg beneath when two eggs in the stick are separated. It sometimes has the appearance of a circle of spinules, owing to the corrugations of the surface upon which it is moulded.

The young larvæ of *Melitara prodenialis*, on hatching from the eggs, feed for a time externally upon the bud-like leaves of Opuntia. When they become larger and stronger they cut through the silicious skin of the pads. The wounds made by them in the plant exude a gummy liquid, and a scab-like crust is formed. Under this the larvæ live in companies, large or small, according to the size of the plant, until they are about one-third grown. After this they burrow deeply into the substance of the succulent stems. The larvæ, as long as they live upon or near the exterior of the plant, are light brown in color, but after they burrow into the pulp and approach their full size, they attain a most beautiful dark-blue color. In pupating they form a loose cocoon of yellow silk, which is concealed somewhere about the Opuntia clump, usually under a prostrate pad.

There appear to be two broods produced during the year, since moths were found issuing in Florida in June and again in October.

### Melitara fernaldialis Hulst.[1]

This species, which occurs in Arizona and New Mexico, has not been found breeding in Opuntia, but was found by Mr. Hubbard to infest the giant cactus, *Cereus giganteus*. In all probability it will be found to attack Opuntias in the region in which it occurs. In fact, in May Mr. F. C. Pratt discovered a larva which may have been of this species in *Opuntia engelmanni* at Tucson, Ariz. This larva discharged its excrement through an opening in the surface of the leaves exactly as does the form which occurs in the western portion of Texas. Apparently the same form was observed by Mr. Pratt at Albuquerque, N. Mex., in June. At Sante Fe, N. Mex., during the same month, about 30 per cent of the plants of *Opuntia arborescens* were more or less injured. Unfortunately, it was impossible to rear any of these larvæ. Our supposition that they were of the species *fernaldialis* is based upon the known range of that form and the fact that they appeared to be different from the Melitara larvæ observed in Texas.

### Gerstæckeria porosa Le Conte.[2]

The presence of the weevil *Gerstæckeria porosa* Le Conte is readily shown by the occurrence of flat discolored areas about three-fourths inch in diameter on the surface of the joints. In the early stages of attack these areas are yellowish, but later become whitish. They cover the cavities excavated by the larvæ.

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[1] Order Lepidoptera, Family Pyralidæ.
[2] Order Coleoptera, Family Curculionidæ.

This species is distributed throughout the cactus region. It has been taken as far north as Denver, Colo., and as far south as San Diego, Tex. Its range extends into Arizona.

The winter is passed in the pupal state within the cells in the Opuntia joints. The adults issue from April to June. There appears to be only one brood during the season. The species is responsible for a large amount of disfiguration of the cactus joints, but as the cells are largely superficial the growth of the plant is not seriously affected. In fact, in no cases observed have the joints been found to be destroyed primarily by the insects. In some cases, however, the cells attract scavengers of various species, which increase the diseased area and may cause the destruction of the joints. The adults appear to feed by scraping the epidermis from the sides of the joint.

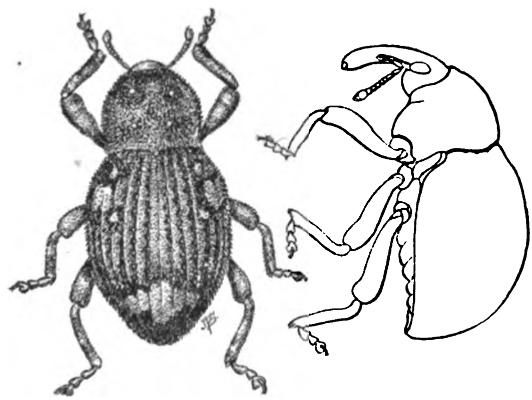


FIG. 3.—A cactus weevil, *Gerstæckeria nobilis*: Adult. Enlarged. (Original.)

**Gerstæckeria nobilis Le Conte.**

The work of *Gerstæckeria nobilis* Le Conte (fig. 3) is precisely like that of the preceding species except that the cells containing the immature stages are located on the margins of the joints. In these localities a hard black exudation frequently forms, and this interferes with the development of new growth. For this reason it is more important than the preceding species, although it is of less extensive distribution. Our records include many localities in Texas from Dallas to Corpus Christi. It does not appear, however, to extend far to the west, Hondo being the westernmost locality in our records.

**Gerstæckeria clathrata Le Conte.**

*Gerstæckeria clathrata* Le Conte works exclusively on *Opuntia leptocaulis*, so far as known, although it may rarely infest allied species. Its work in the plants is similar to that of the other species. It is partial to the new growth, which is often killed. Although thus more destructive than the preceding forms, it is of less economic importance on account of the uselessness of its host. It is recorded from Colorado to Brownsville, Tex., and westward to Arizona.

A fourth species, *G. hubbardi* Le Conte, was reared from *Opuntia vulgaris* in Florida by Mr. H. G. Hubbard. It appeared to follow the work of *Melitara prodenialis* Walker.

The four species described are true cactus insects, being dependent upon the plant for food and places for breeding. Although only four species have been discovered breeding in cactus, it is likely that upon investigation other species of the genus will be found to injure it. The genus contains 22 species, of which 11 are found in the United States and the remainder in Mexico.

It is doubtful whether it will ever be necessary to resort to control measures in the case of any of the species of Gerstæckeria. If control should become necessary, it would be extremely difficult on account of the fact that the immature stages are passed beneath the surface of the joint. No remedy except the removal of the infested joints can be suggested.

**Marmara opuntiella Busck.**[1]

The tineid moth, *Marmara opuntiella* Busck (fig. 4), deposits its eggs just beneath the epidermis of the leaves of Opuntia. The first

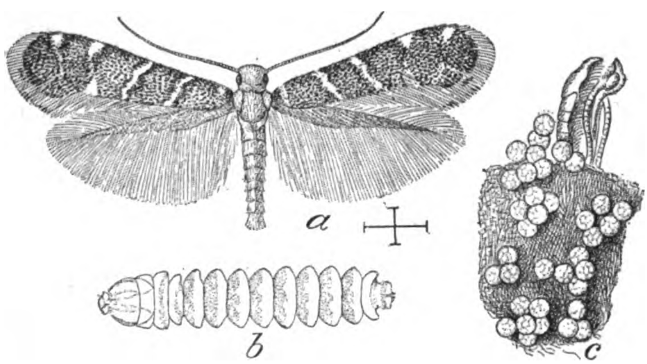



FIG. 4.—A cactus insect, *Marmara opuntiella*: *a*, Adult; *b*, larva; *c*, eggs and pupal case. Enlarged. (Original.)

indication of injury is a slight elevation of the epidermis above the gallery which the larvæ have begun to excavate. The first attack (Pl. VI) is generally near the base of the joint. Later the epidermis above the galleries becomes white and the galleries may cover the entire surface of the joint. This is certain to be the case where several eggs are deposited in one joint. A gummy exudation appears and the whole surface of the joint becomes covered with a yellowish secretion that conceals the mines. The larvæ work immediately beneath the epidermis and never penetrate the interior of the joint. On this account they have little effect upon the growth of the plant. Only on rare occasions when the attack has been directed against the new growth does the joint fall to the ground. The species is widely distributed in Texas, having been taken from New Braunfels southward to Brownsville.

[1] Order Lepidoptera, Family Tineidæ.

The only cases in which it will be necessary to combat this insect will be those in which the new growth of the plants is affected. The only course to follow is to remove these joints and burn them.

## SPECIES INJURING THE BLOOMS.

In the category of species injuring the blooms there is only one that is of importance. This is *Trichochrous* (*Pristoscelis*) *texanus* Le Conte. It is a slender beetle, 3 mm. in length, uniformly olivaceous above, highly polished, with reddish legs, the upper surface of the body covered with rather dense growth of short whitish hairs. It has been collected at southwestern Texas and in New Mexico. At Albuquerque, in the latter State, on June 16, Mr. F. C. Pratt found it in such abundance that no blooms without indications of injury were noticed. The great majority of the plants had been fed upon to such an extent that fruiting had ceased. As many as 153 beetles were found in a single bloom. No larvæ could be found in the vicinity. It is possible that this species is not at all peculiar to cactus, but is to be found in blooms of various kinds. There was a remarkable absence of flowers on all plants except the Opuntias growing at Albuquerque at the time to which reference has been made. This may account for the concentration of the insects in the blooms of the Opuntias and for the damage accomplished. No similar cases had been observed in the numerous observations that had been made in Texas.

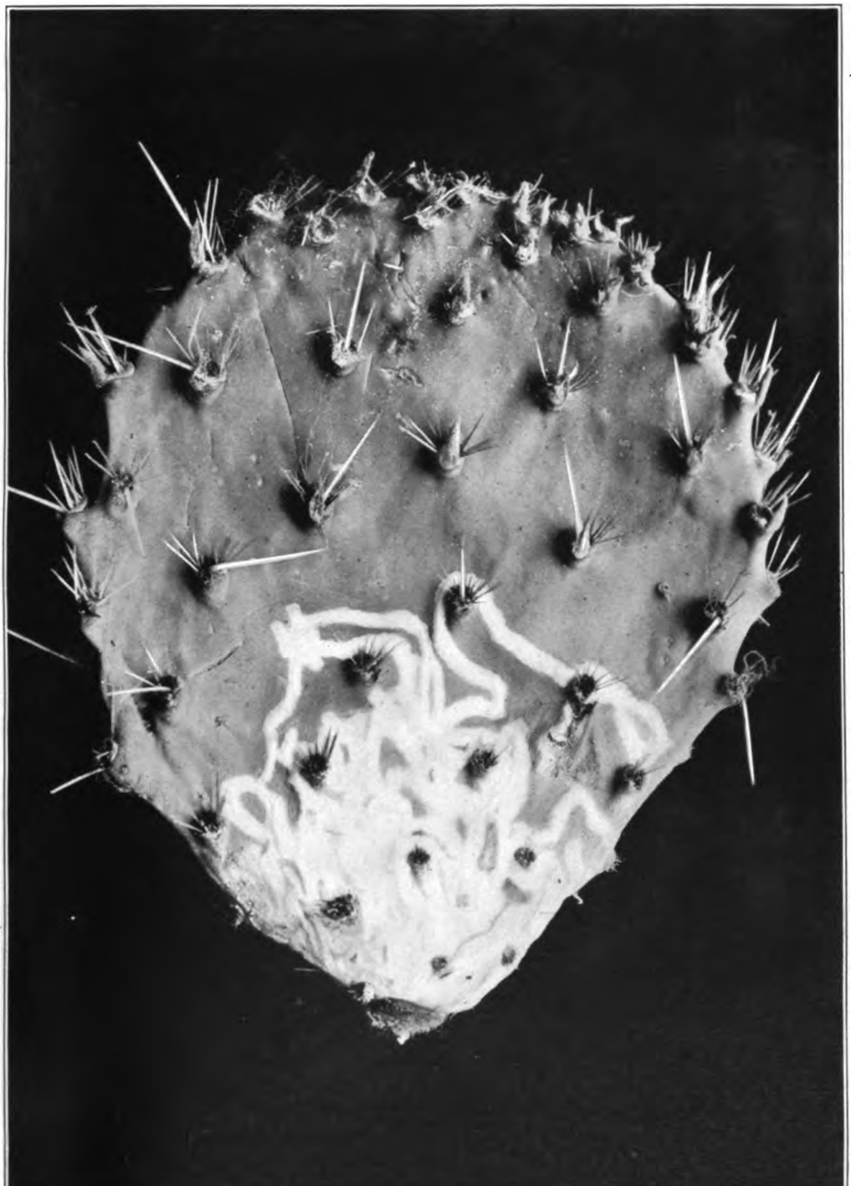
*Euphoria kernii* Haldeman [1] is a very common beetle in cactus blooms in Texas. It is a robust species of very variable color. Some specimens are pure black and all gradations between this form and individuals in which the ground color is yellow, but covered with narrow black stripes, are to be found. The species seems to feed upon the columns and anthers more than upon the petals. Even where it is so abundant that several individuals are to be found in every bloom no special injury to the plants has been detected. On this account the species is included in the list at the end of this bulletin as one which has no other association with the cactus plant than that it frequents the bloom.

## SPECIES INJURING THE FRUIT.

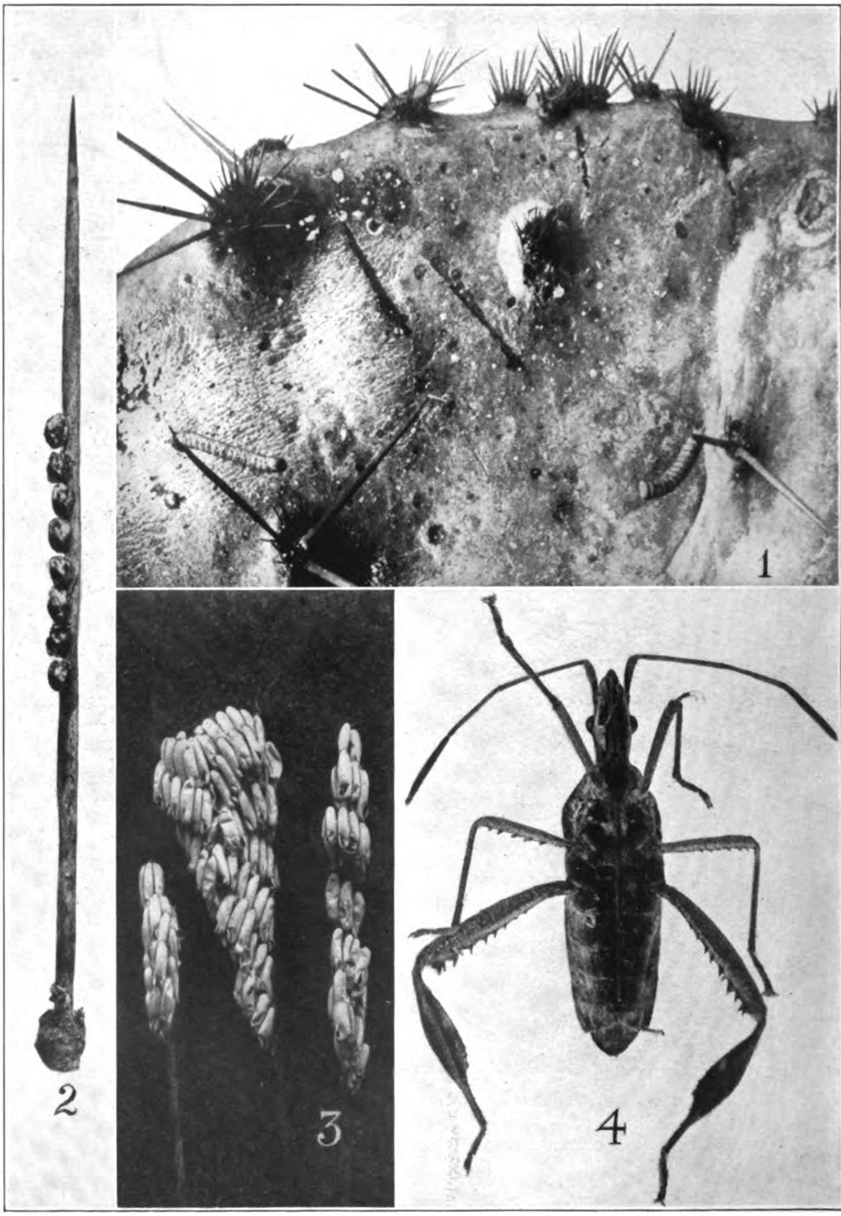
### Narnia pallidicornis Stål.

Of the species that injure the fruit, by far the most important are the bugs of the genus Narnia, the most common being *N. pallidicornis* Stål.[2] The species can be recognized readily. (Pl. VII, fig. 4.) It is of a brownish-yellow color, about 15 mm. in length. The posterior femora are lengthened, very robust, and covered with heavy black

[1] Order Coleoptera, Family Scarabæidæ. [2] Order Hemiptera, Family Coreidæ.



JOINT OF PRICKLY PEAR, SHOWING WORK OF MARMARA OPUNTIELLA. (ORIGINAL.)




STUDIES OF CACTUS INSECTS.

Fig. 1.—Eggs of *Melitara junctolineella* on spines of Opuntia. Fig. 2.—Eggs of *Chelinidea vittigera* on spine of Opuntia. Fig. 3.—Eggs of *Copestylum marginatum* on Opuntia spines. Fig. 4.—*Narnia pallidicornis*. (Original.)

spines. The posterior tibiæ are expanded just beyond the middle into fanlike dilations.

This insect is essentially an enemy of the fruit of the Opuntias. Although it has been observed very commonly in Texas, it has never been found to injure the joints. Like the bugs of the genus Chelinidea, it and its immediate relatives are gregarious in their habits. The range extends from Mineral Wells, Tex., southward to Brownsville and westward to El Paso.

### DESCRIPTIVE.

#### THE EGG.

*Egg.*—Length, 1.5 mm.; width, 1 mm. Dark brown in color, cylindrical, sharply truncate at both ends, surface very finely roughened. Toward the upper end the lid appears as a raised spot with a light ring. Placed with ends contiguous on cactus spines, from 12 to 25 on a spine, sometimes several strings alongside of each other on the same spine. Length of egg stage, about 27 days.

#### THE NYMPHAL STAGES.

*First instar.*—When first hatched, the bugs are slightly less than 4 mm. in length, orange in color, but soon change to a reddish hue. Antennæ brown, 4-jointed, club and first joint equal, second joint slightly longer, basal joint barely one-half the length of the others; all joints covered with hairs, those on the club shorter. Legs reddish, hairy; tarsi dark brown, having shorter hairs. Head reddish; eyes brown; pronotum reddish and armed with a pair of erect spines; abdomen reddish, with four pairs of red spines located on the first, second, fourth, and fifth segments. Margins of abdomen with a row of six erect spines, those at base being longest. Each spine terminates in a short, black, motile bristle. The third and fourth pairs of spines are located on a raised callosity. Length of this stage, 7 days.

*Second instar.*—Length, 5 mm. Antennæ lighter in color than in previous stage, except club, which is dark brown; front and middle pairs of legs yellow, posterior pair darker, dilations on tibiæ now appearing; terminal tarsal joints bearing claw, which is dark brown; head, thorax, and pronotum dark brown; front of head yellow, abdomen reddish. Spines as in first stage, the pronotal spine being twice the length of the others. Length of this stage, 7 days.

*Third instar.*—Length, 6 mm. General color of body brown; antennæ, except club, and front and middle pairs of legs yellow; club of antennæ and posterior legs brown, except joints and tarsi, which are yellow; callosities on pronotum and margins of abdomen whitish, those on abdomen black. An additional pair of spines appears on thorax. Length of this stage, 13 days.

*Fourth instar.*—Length, 9 mm. Antennæ as in third stage. General color dull velvety black and speckled as if dusted with white powder; sparsely covered with shiny, white hairs, those on posterior legs longer and more dense; abdomen reddish beneath. Length of this stage, five days.

*Fifth instar.*—Length, 15 mm. Same coloration as preceding stage, hairs apparently more dense, pronotal spines yellow at base. Thorax well defined. Wing-pads have now appeared, extending over pronotum, yellow. Abdomen yellow, beneath black. Length of this stage, 7 days.

As has been stated, this is an important enemy of the Opuntia plant where the fruits are desired for food. In cactus plantations, however, where the plants are reproduced by cuttings, it is of comparatively little importance. On account of its gregarious habits and its location on the parts of the plant easily reached by a gasoline torch, its control is not a difficult matter.

There are three other species of Narnia which feed upon the fruit of Opuntia and related plants. After *pallidicornis*, the most common species is *femorata*, which is as widely distributed in Texas as that species and extends its range as far westward as Los Angeles, Cal. It has also been taken in Mexico at Aguascalientes, Victoria, and Durango. In general appearance it resembles *pallidicornis* very closely, but is somewhat larger. *N. pallidicornis* has the dilation of the hind tibia narrower, lanceolate shaped, and the inner part of the dilation broadest behind the middle.

The remaining species of the genus which we have observed on cactus are *inornata* and *snowi*. The former has been taken in California and Mexico only, while we have only a single record of the latter species, at Albuquerque, N. Mex., in April.

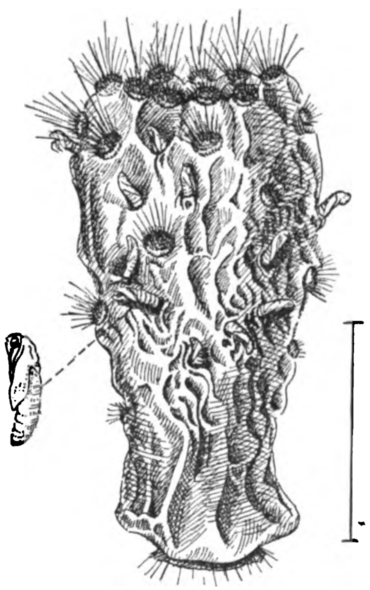


FIG. 5.—Opuntia fruit with puparia of *Asphondylia opuntiæ*. Enlarged. (Original.)

**Asphondylia opuntiæ Felt.**[1]

*Asphondylia opuntiæ* Felt ranks next in importance to the Narnia bugs so far as injury to the fruits of Opuntia is concerned. It is not restricted, however, to the fruits, but sometimes infests the margins of the joints. Its presence is first detected by a yellowish coloration of the fruit or joint and later by the protruding puparia in close groups of sometimes as many as 10 individuals (fig. 5).

This species has a wide range. Specimens have been taken at many points in Texas and southward to San Luis Potosi, Mex., and westward to Los Angeles, Cal. There are evidently several generations in the season, the first adults appearing in southern Texas in March.

Especially in California this species is extremely abundant. On this account it is fortunate that its injury primarily affects the fruit and does not interfere seriously with the growth of the plant. It

[1] Order Diptera, Family Cecidomyiidæ.

can not interfere seriously with the production of forage. It is of greatest importance in Mexico, where the fruit of the Opuntia plant is a very common article of diet for the natives.

Instances of curious deformations of the plant result from the work of this fly. The infested fruit, instead of developing as such, is transformed into a very short joint, which gives rise to a larger or nearly normal joint. The remarkable change in the appearance of the plant caused in this way is sometimes very conspicuous. The result of the work of the same or a similar species was described as an abnormal fruit of *Opuntia ficus-indica* from Caracas by A. Ernst.[1]

Three additional species of Cecidomyiidæ have been reared from Opuntia. They are included in the list at the end of this bulletin, but need not be considered in this connection on account of their very rare appearance.

### Cornifrons elautalis Grote.[2]

*Cornifrons elautalis* Grote is a small grayish moth infesting the green fruits of Opuntia. It was first collected by Mr. J. D. Mitchell in May, 1908, at Hondo, Tex. Later it was taken at Tucson, Ariz., but on the whole seems to be of rare occurrence. The larvæ bore into the fruit to a depth of 1 inch and eject a reddish-colored excrement on the crown of the fruit, causing its death. At Tucson, Ariz., in May, Mr. F. C. Pratt noticed that many fruits were injured by these larvæ. On some plants practically all of the fruits were injured, and it was found that the larvæ traveled from one fruit to another. In that vicinity fully 10 per cent of the fruits were injured.

The larvæ are generally to be found just beneath the corolla, which remains on the crown longer than when the fruit is uninjured. When the corolla falls the larvæ web over the orifice made in the fruit, and the protection is augmented by the addition of the reddish excrement. They also occur in the blooms, but leave them as soon as the flower parts become dry.

It is evident that eggs are generally deposited in the blooms, although this is not by any means invariable. Many fruits were observed in which entry had been gained from the side.

The larvæ are blackish, with a shining black head and narrow, lateral crimson bands.

### Allorhina mutabilis Gory.[3]

Mr. E. A. Schwarz informs us that *Allorhina mutabilis* Gory is a common enemy of the fruit of Cereus in Arizona. It is well known for its damage to fruits of various kinds.

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[1] Nature, November 23, 1882, p. 77.
[2] Order Lepidoptera, Family Pyralidæ.
[3] Order Coleoptera, Family Scarabæidæ.

### Sixeonotus luteiceps Reuter.[1]

The adults of *Sixeonotus luteiceps* Reuter are 3 mm. long, with dark steel-blue wing covers and red head and thorax. The nymphs are bright scarlet. The range of the species is in southwestern Texas. It is not a true cactus insect, although frequently found upon the plant. It seems to prefer yuccas. On these plants it has frequently been observed in great numbers, while Opuntia growing in the immediate vicinity remained uninjured. When cactus plants are attacked the preference seems to be for the ornamental forms of the "pitallo" group. When in large numbers it disfigures these plants considerably, and sometimes causes their death. The first indication of injury is a yellowish discoloration, while the surface is covered by numerous black specks of excrement.

### Polistes spp.[2]

Two species of wasps of the genius Polistes, namely, *rubiginosus* and *texanus*, have been taken commonly in Texas, and one, *flavus*, was taken on Cereus in Arizona by Mr. H. G. Hubbard. The adults of these species are found everywhere on the fruit of Opuntia and other cacti. They cut open the partially ripened fruit with their mandibles and feed upon the juices that exude. They are of very little importance from the standpoint of the cultivation of the plant.

### Liotropis contaminatus Uhler.[3]

The species *Liotropis contaminatus* Uhler, recorded by Prof. H. Osborn[4] on fruit of *Opuntia fulgida* near Tucson, Ariz., occurs also at El Paso, Tex., and in the Inyo Mountains, Cal., at the latter locality at an elevation of 7,000 to 9,000 feet.

### Dytopasta yumaella Kearfott.

Reared from Opuntia fruit collected at Hondo, Tex., by Mr. J. D. Mitchell in June. Also taken in Arizona.

### Ozamia lucidalis Walker.

Observed at Victoria, Austin, San Antonio, and Hondo, Tex. Larva moves from fruit to fruit, thus destroying sometimes as many as five. Cocoon whitish, silky, unmixed with foreign matter, placed on side of fruit. Evidently widespread, but never abundant.

### Platynota rostrana Walker.

Reared from Opuntia fruit collected at Brownsville, Tex., in May by Mr. J. D. Mitchell. This is the only record we have obtained.

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[1] Order Hemiptera, Family Capsidæ.
[2] Order Hymenoptera, Family Vespidæ.
[3] Order Hemiptera, Family Pentatomidæ.
[4] Ent. News, vol. 20, p. 177, 1906.

## SCAVENGERS.

In the list of insects found associated with the cactus plant at the end of this bulletin we have included 73 species in the category of scavengers. Many of these species feed only upon the joints when these have been killed by other insects or when they are blown to the ground. A considerable number of the scavengers, however, breed in the living joints, obtaining entrance through the mines of Moneilema, Melitara, and other forms. The diseased condition caused primarily by the original inhabitant of the joint is increased by the work of such scavengers. They are therefore incidentally injurers of the plant. The cavities they inhabit become infested by various fungi and bacteria and the diseased area increases in size when, without the intervention of these scavengers, the plant would be able to heal the wound.

### Copestylum marginatum Say.[1]

The most common of the scavengers which increase the effects of the attack of other insects is *Copestylum marginatum* Say (fig. 6). The adults of this fly are to be found about the cactus plant from March to October. They are also taken commonly in the blooms of a long list of plants found in the cactus region. Undoubtedly they breed in decaying vegetation of all kinds, but one of the most important breeding places is the joints of cactus that have been injured by Melitara, Moneilema, Gerstæckeria, and other forms. Very soon the interior of the joint becomes filled with a dark, malodorous liquid, which undoubtedly causes the rapid decay of the plant tissues.

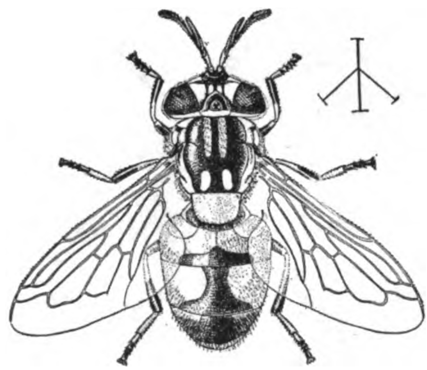

FIG. 6.—A cactus insect, *Copestylum marginatum:* Adult. Enlarged. (Original.)

The adult fly deposits its eggs on the spines in large masses. (Pl. VII, fig. 3.)

The larva of this species measures 20 mm. by 4 mm.; the tail is 1 mm. in length. It is shining, its skin wrinkled. In color it is white, the tail dark brown. Each ventral segment has two almost contiguous oval areas of very short, stout, brownish spines, and there are similar spines on the head segment. The puparium is 10 mm. by 4 mm., calcareous, its surface dirty whitish, covered with particles of sand. There are many annulations of spinose areas, more distinct beneath.

[1] Order Diptera, Family Syrphidæ.

In the same category as the preceding species are four species of the closely allied genus Volucella, namely, *esuriens*, *avida*, *pusilla*, and *fasciata*. They have been found numerously in practically all localities where cactus insects have been collected, occurring frequently with *Copestylum marginatum* Say and other species.

### Hermetia spp.[1]

Almost equally important are two species of Hermetia, namely, *chrysopila* (fig. 7) and *hunteri*. The former is much more abundant and occurs from Dallas, Tex., southward to San Antonio and westward as far as Los Angeles, Cal.

The larvæ of *Hermetia chrysopila* Loew measure 35 mm. by 10 mm., the tail 2 mm. The integument is very tough and leathery, dark brown, its surface densely and evenly punctured, with indistinct transverse rows of callosities near the posterior third. The head is deeply, longitudinally impressed below, with two longitudinal ridges above.

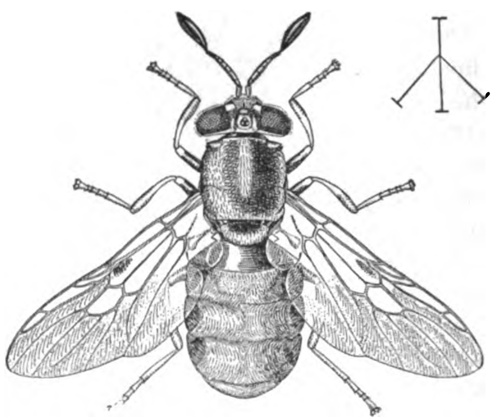

Fig. 7.—A cactus insect, *Hermetia chrysopila*: Adult. Enlarged. (Original.)

This species has been collected from April until September and has been observed depositing eggs in the empty cells of Gerstæckeria as well as in the openings made by Melitara and other species. It is not at all restricted to cactus, but undoubtedly breeds in decaying vegetable matter of any description. The adults are found in flowers of many species as well as in those of Opuntia.

The most remarkable observation made on this species relates to the longevity of the larva. In May, 1909, a number of specimens which appeared to be nearly full grown were taken at Hondo, Tex., by Mr. J. D. Mitchell. They were placed in breeding cages, from which adults appeared irregularly between July 17 and August 19. Some of the larvæ, however, did not yield adults. They remained motionless in the bottom of the cages. Whenever a new supply of food in the form of decaying cactus was introduced they began feeding, but as soon as the food dried they became quiescent. After it was observed that they were of rather remarkable longevity no food was introduced for over a year. The larvæ lived for more than 15 months without food and developed readily later when food was sup-

[1] Order Diptera, Family Stratiomyiidæ.

plied. The very leathery integument seems to protect the insect against desiccation, and in other ways the larva has evidently adapted itself to long periods of waiting for favorable food, which, in the arid regions, depends upon the infrequent rains.

**Stictomyia longicornis Bigot.**[1]

The *Stictomyia longicornis* of Bigot is an exceedingly common insect throughout the cactus area. The adults are small flies with spotted wings. The wings are bent downward at about the middle, so that the name of "droop-winged fly" seems appropriate. (See fig. 8.) The larvæ occur along with Copestylum, Volucella, and Hermetia in any part of the cactus plant that may be injured. They also infest wounds made by knives when cuttings are removed for planting.

The remaining insects listed as scavengers are of less general occurrence than the species mentioned in the preceding pages and no special notes have been made upon them.

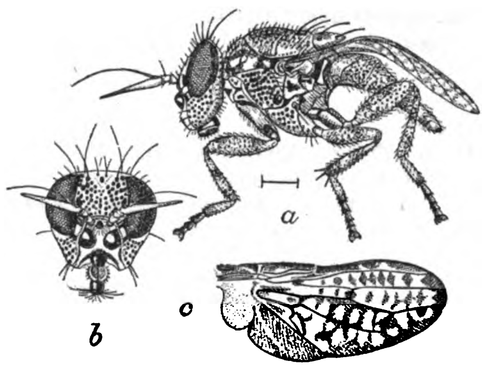

FIG. 8.—A cactus insect, *Stictomyia longicornis*: *a*, Adult in profile; *b*, head; *c*, wing. Enlarged. (Original.)

## LIST OF THE PRINCIPAL CACTUS INSECTS OF THE UNITED STATES.

The following list deals primarily with the species attacking or associated with the genus Opuntia and includes all published records of previous investigators. Many forms not restricted to Opuntia are included because, as Mr. Schwarz has pointed out, the insects of that plant are interchangeable with those of other plants of the family Cactaceæ. For this reason we have included all of the records of species taken on *Cereus giganteus* in Arizona by Mr. H. G. Hubbard.[2] The names of such species are preceded by an asterisk. We have also included references to some exotic species, principally from Mexico.

The published records of cactus insects, including those of Mr. Hubbard, deal with 105 species. The present list includes 324 species. These are divided, for convenience, into the following groups: Injurious 92, parasitic or predaceous 28, scavengers 73, visitors of flowers 40, incidental 91.

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[1] Order Diptera, Family Ortalidæ.

[2] Except *Platydema inquilinum* Linell, which was taken in a rat's nest.

The determinations in all cases have been made by the recognized authorities in the different groups. We are indebted to the following entomologists for assistance in this connection: E. A. Schwarz, H. G. Dyar, W. M. Wheeler, Otto Heidemann, W. D. Pierce, J. C. Crawford, and S. A. Rohwer. Mr. Schwarz also rendered most valuable aid in making suggestions throughout the course of the work and in reading the manuscript and proofs.

We are especially indebted to Prof. T. D. A. Cockerell for furnishing complete lists of Opuntia bees and for making many suggestions about the portion of the list dealing with the Coccidæ.

## SPECIES WHICH INJURE THE PLANT.

### ARACHNIDA.

*Tetranychus opuntiæ* Banks. Reported by Mr. David Griffiths as injurious, but not taken in present investigations.

### ISOPTERA.

*Termes flavipes* Kollar. Sabinal, Tex., September (F. C. Pratt); Falfurrias and Hondo, Tex. (J. D. Mitchell).

Attacks young Opuntia plants, also Cereus; frequently nests in decaying Opuntia and constructs covered galleries on joints.

### HEMIPTERA.

*Liotropis contaminatus* Uhler. Tucson, Ariz.; El Paso, Tex. (H. F. Osborn).
Feeding on fruit of *Opuntia fulgida.*

*Chelinidea tabulata* Burmeister. Durango, Aguascalientes, and Victoria, Mex.; Tucson, Ariz.; Brewster County, Devils River, Oakville, Victoria, Austin, Hondo, and San Antonio, Tex. Throughout the season.
Feeds on joints.

*Chelinidea vittigera* Uhler. Colorado, Abilene, San Antonio, Knickerbocker, Trinity, Cotulla, Tivoli, Boerne, Encinal, Victoria, San Diego, Kerrville, Dallas, Oakville, Chisos Mountains, Mineral Wells, Hallettsville, Sabinal, Hondo, Falfurrias, Laredo, Fredericksburg, El Paso, and Austin, Tex. Throughout the season.
Feeds on joints.

*Chelinidea* sp. Tucson, Ariz., May (F. C. Pratt).
Feeding on joints of *Opuntia fulgida.*

*Largus succinctus* Linnæus. San Antonio, Tex., July (F. C. Pratt).
Feeding on joints of *Opuntia arborescens.*

*Lopidea cuneata* Van Duzee. Los Angeles, Cal., June (F. C. Pratt).
Feeds on joints of Opuntia.

*Oncerometopus nigriclavus* Reuter. Kerrville, Tex., August (F. C. Pratt); D'Hanis, Tex.. April (J. D. Mitchell).
Feeding on joints of Opuntia.

*Hadronema robusta* Uhler. San Antonio, Tex., June (J. C. Crawford).
Feeding on joints of Opuntia.

*Stylopidea picta* Uhler MS. Victoria and D'Hanis, Tex., April (J. D. Mitchell); San Antonio, Tex., April (J. C. Crawford); Hondo, Austin, and Corpus Christi, Tex., May (F. C. Pratt); Brownsville, Tex., February (C. R. Jones and F. C. Pratt); Beeville, Tex. (E. A. Schwarz).

Feeds on joints.

*Sixeonotus luteiceps* Reuter. Hondo, Tex., May (J. D. Mitchell); Brownsville, Tex., March (C. R. Jones and F. C. Pratt).

Feeds on joints; especially partial to *Echinocereus* spp.; also taken on yucca and other plants.

*Macrotylus verticalis* Uhler (?). Los Angeles, Cal., June (F. C. Pratt).

Feeds on joints of Opuntia.

*Corythuca decens* Stål. Aguascalientes, Mex., December (F. C. Pratt).

On Opuntia.

Tucson, Ariz., June (J. W. Toumey).

Feeding on Opuntia joints.

*Proarno valvata* Uhler. Albuquerque, N. Mex., May (F. C. Pratt).

Apparently feeding on Opuntia joints.

*Narnia femorata* Stål. Taken at the following localities in Texas throughout the season: Mineral Wells (C. R. Jones); D'Hanis, Cotulla, Corpus Christi, Victoria, and Hebbronville (J. D. Mitchell); Hondo, Zavalla County, Sabinal, San Antonio, Kerrville, El Paso, and Llano (F. C. Pratt); also taken at Los Angeles, Cal., and Tucson, Ariz. (F. C. Pratt), and at Aguascalientes, Victoria, and Durango, Mex. (F. C. Bishopp).

Feeds on fruit of Opuntia and on Cereus; very destructive.

* *Dendrocoris contaminatus* Uhler, Tucson, Ariz.

*Narnia pallidicornis* Stål. Taken in Texas at localities below: Cotulla, Kerrville, El Paso, Sabinal, Austin (F. C. Pratt); Alice, Hondo, San Antonio, D'Hanis, Hebbronville, San Diego, Victoria, Encinal, and Oakville (J. D. Mitchell); Mineral Wells (C. R. Jones).

Occurs throughout the season; very destructive to fruits.

*Narnia inornata* Distant. Los Angeles, Cal., May (F. C. Pratt); Durango, Mex., November (F. C. Bishopp).

Feeds on joints.

*Narnia snowi* Van Duzee. Albuquerque, N. Mex., April (F. C. Pratt).

Feeds on joints.

*Platypedia putnami* Uhler. Albuquerque, N. Mex., June (F. C. Pratt).

Feeds on Opuntia joints.

*Platymetopius fuscifrons* Van Duzee. D'Hanis, Tex., April (J. D. Mitchell).

Feeds on joints.

*Dictyobia permutata* Uhler. Corpus Christi, Tex. (F. C. Pratt and A. C. Morgan).

Feeds on joints.

*Aphis medicaginis* Koch (det. C. E. Sanborn). Tucson, Ariz., May (F. C. Pratt); Hackberry, Ariz. (D. Griffiths); Dallas, Tex. (F. C. Pratt).

On Opuntia. Mr. Sanborn informs us that in Texas the species probably passes the winter on Opuntia.

*Margarodes* sp. (?). Montserrat, W. I. (C. V. Riley). According to Prof. Cockerell (in litt.) the species is undoubtedly *M. formicarum* (Guild.).

On Cereus roots.

*Eriococcus coccineus* Cockerell San Bernardino, Cal., September; also from greenhouse in Nebraska.

On joints.

*Dactylopius confusus* Cockerell. (Cottony cochineal insect.) Throughout the cactus region from Graham County, Ariz., southward, Texas, Florida, and California.

Feeds on joints of all species of Opuntia.

Also present in hothouses throughout the country.

*Dactylopius* (*Coccus*) near *confusus*. Barbados, W. I., May (D. D. Morris).

*Dactylopius coccus* Costa. (Cochineal insect.) Recorded from California and Florida, but probably introduced. Introduced in West Indies, Canaries, India, Peru, Spain, and other Mediterranean countries.

*Dactylopius tomentosus* Lamarck. Guanajuato, Mex., July (T. D. A. Cockerell); New Mexico; Arizona.

On *Opuntia fulgida* joints.

*Dactylopius* (*Coccus*) sp. Cape Town, South Africa (A. M. Cooper).

On *Opuntia polyantha.*

*Dactylopius* (*Coccus*) sp. Colorado Desert, Cal., January (D. W. Coquillett). San Bernardino, Cal.

*Pseudococcus virgatus* Cockerell. Brownsville, Tex.

On "Jacobo" cactus. (See also Cockerell, Can. Ent., 1895, p. 259.)

*Pseudococcus obscurus* Essig. California.

On roots of Opuntia.

*Pseudococcus longispinus* Targioni-Tozzetti (Syn.: *Dactylopius longifilis* Comstock).

(See Lintner, 2d N. Y. Report, p. 56.)

On prickly pear at Waterbury, Conn.

*Pseudococcus* sp. Mesilla Park, N. Mex., April (D. Griffiths).

On joints of *Opuntia cycloides.*

*Ripersia* sp.

On roots of cactus.

*Diaspis cacti* Comstock. Arizona and New Mexico.

On *Opuntia fulgida*, *O. arborescens*, and *O. engelmanni.*

*Diaspis cacti opunticola* Newstead. Demarara.

*Diaspis echinocacti* Bouché. According to Mrs. Fernald, Europe, India, Algeria, Porto Rico, Mexico, New Mexico, New York.

On *Opuntia ficus-indica*, *Echinocactus ottonis*, and *E. tenuispinus*, etc.

*Diaspis echinocacti cacti* Comstock. Laredo, Tex., March, on *Opuntia leptocaulis* and *O. lindheimeri* (F. C Pratt); San Antonio, Tex. (J. D. Mitchell); Arizona and New Mexico, on *O. fulgida*, *O. arborescens*, and *O. engelmanni* (T. D. A. Cockerell). According to Mrs. Fernald, Massachusetts and New York (greenhouses), Iowa, Arizona, New Mexico, Brazil, India, Mauritius, on Cactus, *Cereus giganteus*, *C. macrogonus*, *Echinocactus* sp.

*Diaspis echinocacti opuntiæ* Cockerell. Kingston, Jamaica (T. D. A. Cockerell); Sierra Blanca, Tex., on *Opuntia arborescens* (C. H. T. Townsend); Demarara, Texas, Mexico, on *O. arborescens* and *O. elongata.*

*Pseudoparlatoria parlatorioides* Comstock. Frontera, Mex. (C. H. T. Townsend).

*Lepidosaphes* (*Opuntiaspis*) *philococcus* Cockerell. On Opuntia in Mexico, according to T. D. A. Cockerell in litt.

### COLEOPTERA.

*Trichochrous* (*Pristoscelis*) *texanus* Le Conte. Albuquerque, N. Mex., June, Zavalla County, Tex. (F. C. Pratt); D'Hanis and Brownsville, Tex. (J. D. Mitchell).

Occurs in great numbers in blooms, which are sometimes considerably injured.

*Allorhina mutabilis* Gory. According to Mr. E. A. Schwarz feeds on fruit of Cereus.

*Moneilema ulkei* Horn. Cotulla, Falfurrias, and Brownsville, Tex. (J. D. Mitchell); Sabinal, Tex. (F. C. Pratt); Oakville, Tex. (F. C. Bishopp).
Larvæ in roots; adults feed on joints.

*Moneilema variolare* Thomson. Mexico (Dugès).
Breeds in "Cactus Opuntia."

*Moneilema annulatum* Say.
On Opuntia in Kansas (Popenoe.)

*Moneilema semipunctatum* Le Conte.
On Opuntia in Kansas (Popenoe.)

*Moneilema crassum* Le Conte. Cotulla and Maverick counties, Tex., May (J. D. Mitchell); Encinal, El Paso, and Sabinal, Tex., April to September (F. C. Pratt).
Larvæ in roots; adults feed on joints.

*Moneilema spoliatum* Horn. Encinal, Tex., May (D. Griffiths).
Larvæ in roots; adults feed on joints.

*Moneilema lævithorax* White. Mex.

* *Moneilema gigas* Le Conte.

*Moneilema armatum* Le Conte.

*Moneilema* sp. Falfurrias, Tex., April (J. D. Mitchell).

*Cœnopœus palmeri* Le Conte. Bred from stems of *Opuntia bernardina*, Southern California.

*Disonycha varicornis* Horn. Devils River, Tex., May (E. A. Schwarz and F. C. Pratt); San Antonio and Austin, Tex., April, August, and June (F. C. Pratt). Confined to *Opuntia leptocaulis* and similar species.

*Gerstæckeria hubbardi* Le Conte. Breeds in the joints of *Opuntia vulgaris* following injury by *Melitara* sp.; taken at Crescent City and Lake Worth, Fla., and Selma, Ala. (H. G. Hubbard and E. A. Schwarz).

*Gerstæckeria bifasciata* Gerstaecker. Reared November 1, 1910, by F. L. Lewton from *Echinocactus setispinus* collected in June at San Antonio, Tex.

*Gerstæckeria nobilis* Le Conte. Breeds in the margins of the joints of *Opuntia engelmanni* and causes great masses of black excrement and gum to form on the outside of the joint. It has been taken at Dallas, Tex. (J. Boll); San Antonio, Tex., November (H. Soltau); San Diego, Tex., April, May, September (E. A. Schwarz); Beeville, Tex., April, eating fruit of Opuntia (C. L. Marlatt); Cotulla, Tex., April (F. C. Pratt); Live Oak County, Tex., June (J. D. Mitchell); Floresville, Tex., October (F. C. Pratt); Corpus Christi, Tex., May (A. C. Morgan), March (W. E. Hinds); Hondo, Tex., April (J. D. Mitchell); College Station, Tex., March (W. D. Pierce); Encinal, Tex., April (J. D. Mitchell); Victoria, Tex., April (J. D. Mitchell).

*Gerstæckeria porosa* Le Conte. Denver, Colorado Springs, Colo. (Wickham and Soltau); Sedalia, Colo. (H. Soltau); Albuquerque, N. Mex. (H. Soltau); Mesilla Park, N. Mex. (C. N. Ainslie); Kansas (Snow); Fort Grant, Ariz. (H. G. Hubbard and E. A. Schwarz); San Diego, Tex. (H. G. Hubbard and E. A. Schwarz); Floresville, Tex. (F. C. Pratt); Live Oak County, Tex. (J. D. Mitchell); D'Hanis, Tex. (J. D. Mitchell); Hondo, Tex. (F. C. Pratt).

The species breeds in flat cells in the discs of the joints of Opuntia.

*Gerstæckeria basalis* Le Conte. Denver, Colo. (H. Soltau); Greeley and Canon City, Colo. (H. Soltau); Sioux County, Nebr. (R. H. Wolcott).

*Gerstæckeria clathrata* Le Conte. San Diego, Tex., April and May, Laredo, Tex. May (H. G. Hubbard and E. A. Schwarz); Hidalgo, Tex. (G. Beyer); Uvalde, Tex., June (H. F. Wickham); Brownsville, Tex., June (C. H. T. Townsend); Santa Rita Mountains, Ariz., May (H. G. Hubbard and E. A. Schwarz).

Breeds in *Opuntia leptocaulis.*

*Gerstæckeria turbida* Le Conte. Catalina Springs, Ariz., April (H. G. Hubbard and E. A. Schwarz); Tucson, Ariz., January (H. G. Hubbard and E. A. Schwarz); Fort Grant, Ariz., July (H. G. Hubbard and E. A. Schwarz).

*Gerstæckeria opuntiæ* Pierce. Encinal, Tex., April (J. D. Mitchell).

*Gerstæckeria cactophaga* Pierce. Port Isabel, Tex., May (H. S. Barber); Brownsville, Tex. (C. H. T. Townsend).

*Onychobaris mystica* Casey. Southern Texas, Arizona, and New Mexico, on *Opuntia leptocaulis* (E. A. Schwarz); Tucson, Ariz., in *O. fulgida.*

**Cactophagus spinolæ* Gyllenhal (Syn.: *validus* Le Conte). (See Champion, Biol. Centr.-Amer.) California, Arizona, Mexico, many localities. Larva and pupa figured by Dugès (La Naturaleza, vol. 5, 121).

According to Dugès breeds in "*Cactus opuntia.*"

*Cactophagus striatoforatus* Gyllenhal. Attacks Cereus in Costa Rica and Colombia. (See Champion, Biol. Centr.-Amer., Coleoptera, vol. 4, 7, p. 84.

* *Cactopinus hubbardi* Schwarz. Forms mines in Cereus.

## LEPIDOPTERA.

*Apantesis arge* Drury.

Feeding on cactus. (See Forbes, 23d Rept. Ins. Ill., p. 777, 1905.)

*Chorizagrotis soror* Smith. San Antonio, Tex., February (D. Griffiths).

Larvæ had formed canals through underground portions of plants. A serious enemy of young plantings. According to Dr. Dyar, it is probably a general feeder and not confined to cactus.

*Mimorista flavidissimalis* Grote. Widespread in Texas, south of San Antonio and west of Victoria. Brownsville, Victoria, and Beeville (J. D. Mitchell), San Antonio and Sabinal (F. C. Pratt); May to September. A very destructive insect, attacking joints of Opuntia.

*Cornifrons elautalis* Grote. Hondo, Tex. (J. D. Mitchell); Tucson, Ariz. Destructive to fruit.

*Dicymolomia opuntialis* Dyar. San Diego and Riverside, Cal., May (D. Griffiths). Apparently forms mines in joints, but doubtfully included in this list. See following species.

*Dicymolomia julianalis* Walker. Brownsville and Kerrville, Tex., June. Apparently forms mines in joints, but it is very doubtful whether it should be considered a cactus insect. Gahan (Proc. Ent. Soc. Wash., vol. 11, p. 66) records it as a predator on the eggs of *Thyridopteryx ephemeræformis* Haworth.

*Ozamia lucidalis* Walker. Victoria, San Antonio, and Hondo, Tex., May (J. D. Mitchell). Infesting fruit.

*Melitara junctolineella* Hulst. Kerrville, Tex. (H. Lacy); Corpus Christi, Victoria, Beeville, Hondo, Laredo, Tex. (J. D. Mitchell); El Paso, Kerrville, San Antonio, Tex. (F. C. Pratt). This and the other species of the genus live within the joints of Opuntia, causing large swellings. The two different kinds of cocoons seem to indicate that there are two species present in the cactus area. The range of the two forms corroborates this supposition. There are certain differences between the specimens, but they are not sufficient to separate the series into two forms.

*Melitara prodenialis* Walker. Florida (H. G. Hubbard); New Jersey (J. B. Smith); Biloxi, Miss., September (W. W. Tracy).

*Melitara dentata* Grote. Trinidad, Colo. (D. Griffiths).

**Melitara fernaldialis* Hulst. Santa Fe and Albuquerque, N. Mex., and Tucson, Ariz. (F. C. Pratt), on Opuntia; Tucson, Ariz. (H. G. Hubbard), on *Cereus giganteus*.

*Platynota rostrana* Walker. Brownsville, Tex., May (J. D. Mitchell).

Reared from Opuntia fruit. Reared in Florida by Dyar from Rivinia, Randia, and Gnaphalium.

*Dyotopasta yumaella* Kearfott. Brownsville, Tex. (J. D. Mitchell) and Arizona.

Breeds in fruit of Opuntia.

*Marmara opuntiella* Busck. At the following localities in Texas: Corpus Christi, Brownsville (J. D. Mitchell), San Antonio, Kerrville (F. C. Pratt), Marble Falls, New Braunfels (D. Griffiths). Mines beneath epidermis of joints.

### HYMENOPTERA.

*Polistes rubiginosus* Lepeletier. Corpus Christi, Tex., August (J. D. Mitchell). This and the following species feed as adults on cracked fruit and sometimes on sound fruit of Opuntia.

* *Polistes flavus* Cresson. Arizona (H. G. Hubbard).

*Polistes texanus* Cresson. Alice, Brownsville, Corpus Christi, Tex., October (J. D. Mitchell); San Antonio, Tex. (F. C. Pratt).

### DIPTERA.

*Cecidomyia opuntiæ* Felt. Reared in New York from joints of a European Opuntia (*O. banburjana*) and also from a West Indian species.

*Asphondylia opuntiæ* Felt. Los Angeles, Cal., April (D. Griffiths); Ash Fork, Ariz., May (D. Griffiths); Organ Mountains, N. Mex., January (D. Griffiths); Sinton, Victoria, Kennedy, Corpus Christi, Brownsville, Hondo, Cotulla, and Hallettsville, Tex. (J. D. Mitchell); Beeville, Tex., March (F. C. Pratt); San Luis Potosi, Mex. (D. Griffiths).

Breeds in fruit of Opuntia.

*Asphondylia betheli* Cockerell. Colorado.

In fruit of Opuntia.

*Asphondylia arizonensis* Felt. Arizona.

Reared from "enlargement of prickly pear."

## PARASITES OR ENEMIES OF THE INJURIOUS SPECIES.

### HEMIPTERA.

* *Sinea raptoria* Stål. Tucson, Ariz.

* *Diplodus luridus* Stål. Tucson, Ariz.

### COLEOPTERA.

*Exochomus latiusculus* Casey. Corpus Christi, Seguin, San Antonio, Tex., March, October (F. C. Pratt); Cotulla and Beeville, Tex., April (J. D. Mitchell).

*Exochomus marginipennis* Le Conte. Corpus Christi, Hondo, Tex. (J. D. Mitchell); Seguin, Tex., October (F. C. Pratt).

*Hippodamia convergens* Guérin. Los Angeles, Cal., June (F. C. Pratt).

Feeds on aphides on Opuntia.

*Cycloneda munda* Say. Hondo, Tex., April (J. D. Mitchell).

*Chilocorus cacti* Linnaeus. Durango, Mex., November (F. C. Bishopp).

*Hyperaspis trifurcata* Schæffer. Hebbronville, Falfurrias, Floresville, Corpus Christi, Victoria, San Diego, Tex., May to August (J. D. Mitchell); Seguin, Alice, San Antonio, Kerrville, Tex. (F. C. Pratt); Durango, Mex. (F. C. Bishopp).

*Hyperaspis cruenta* Le Conte. Mesilla Park, N. Mex., June (D. Griffiths); Brewster County, Tex. (R. A. Cushman); El Paso, Tex., August (F. C. Pratt).

*Scymnus loewii* Mulsant. Brownsville, Tex., March (F. C. Pratt); Aguascalientes, Mex., December (F. C. Bishopp).

*Scymnus hornii* Gorham. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp). The nine preceding species (except *Hippodamia convergens*) are enemies of *Dactylopius confusus*.

*Bothrideres cactophagi* Schwarz. Enemy of *Cactophagus validus*.

*Trichodes bibalteatus* Le Conte. Cotulla, Tex., May (J. D. Mitchell); Dallas, Tex., May (F. C. Pratt).

Feeds upon Melitara and other insects.

*Hydnocera pubescens* Le Conte. Victoria, Tex., May (R. A. Cushman).

Feeds upon various cactus species.

## LEPIDOPTERA.

*Lætilia coccidivora* Comstock. Cotulla, Tex., October.

Enemy of *Dactylopius confusus*.

*Zophodia dilatifasciella* Ragonot. San Antonio, Tex., June (D. Griffiths); Brown and Young Counties, Tex. (J. D. Mitchell).

Feeding on *Dactylopius confusus*.

*Saluria ardiferella* Hulst. Mesilla Park, N. Mex., June.

Feeds upon *Dactylopius confusus*.

## HYMENOPTERA.

*Mesostenus thoracicus* Cresson. Corpus Christi, Tex., March (F. C. Pratt).

Probable parasite of *Melitara* spp.

*Eiphosoma texana* Cresson.

Parasite of *Mimorista flavidissimalis* Grote.

*Eurytoma* sp. D'Hanis, Tex., May (J. D. Mitchell).

*Chelonus laticinctus* Cresson. Trinidad, Colo., August.

Parasite of *Melitara dentata* Grote.

*Apanteles* (*Pseudapanteles*) sp. Corpus Christi, Tex., April (W. D. Pierce). At *Opuntia lindheimeri*.

Possible parasite of Melitara.

*Apanteles* sp. Victoria, Tex., September (J. D. Mitchell).

Possible parasite of Melitara.

## DIPTERA.

*Phorocera comstocki* Williston. Victoria, Tex., October (J. D. Mitchell); San Antonio, Cotulla, Corpus Christi, Tex., October (F. C. Pratt).

Parasite of Melitara.

*Drosophila punctulata* Loew. San Antonio, Tex., April, May (D. Griffiths); Victoria, Tex., April, December (J. D. Mitchell); Brownsville, Tex., March (F. C. Pratt).

Feeds upon *Dactylopius confusus*.

*Drosophila ampelophila* Loew. Berkeley, Cal., June (D. Griffiths).
Feeds upon *Dactylopius confusus.*

*Leucopis bella* Loew. San Antonio, Tex., May (D. Griffiths); San Diego and San Bernardino, Cal.
Enemy of *Dactylopius confusus.*

*Leucopis bellula* Williston. Texas, New Mexico, and Mexico.
Enemy of *Dactylopius confusus.*

## SCAVENGERS.

### COLEOPTERA.

**Megasternum cerei* Schwarz.
**Dactylosternum cacti* Le Conte.
**Pelosoma capillosum* Le Conte.
**Eumicrus lucanus* Horn.
**Tyrus elongatus* Brendel.
**Melba puncticollis* Le Conte.
**Falagria* sp.
**Homalota* sp.
*Aleochara* sp. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp).
*Maseochara valida* Le Conte. Reared by Coquillett from puparium of *Copestylum marginatum* Say in *Opuntia engelmanni* at Los Angeles, Cal.
**Maseochara semivelutina* Solsky.
**Maseochara spacella* Sharp.
**Maseochara puberula* Casey.
*Maseochara* sp. Arizona, June (F. C. Pratt).
**Apheloglossa rufipennis* Casey.
*Aleocharine, genus unknown.
**Oligota* sp.
**Xanthopygus cacti* Horn.
*Belonuchus ephippiatus* Say.
*Belonuchus xanthomelas* Solsky. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp). Victoria and Hondo, Tex., December (J. D. Mitchell).
**Xantholinus dimidiatus* Le Conte.
**Lithocharis tabacina* Casey.
*Tachinoderus grandis* Sharp. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp).
**Erchomus punctipennis* Le Conte.
**Erchomus convexus* Erichson. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp).
**Physetoporus grossulus* Le Conte.
*Leptochirus edax* Sharp. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp).
**Omalium cacti* Schwarz.
**Trichopteryx* sp.
**Ephistemus cactophilus* Schwarz.
*Attagenus piceus* Olivier. D'Hanis and Encinal, Tex., May (J. D. Mitchell).
**Attagenus hornii* Jayne.
*Carcinops* sp. Aguascalientes, Mex., December (F. C. Bishopp).
*Hololepta cacti* Le Conte. San Antonio, Sabinal, and Hondo, Tex., May (F. C. Pratt); Victoria, Cotulla, Corpus Christi, Laredo, Tex. (J. D. Mitchell).

**Hololepta vicina* Le Conte.

*Hololepta yucateca* Marseul. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp). According to Mr. E. A. Schwarz this species follows the attack of other species in Cereus and is of some importance in this connection.

*Hololepta strigicolle* Marseul. Mexico (Dugès).

**Paromalus opuntiæ* Le Conte.

**Paromalus consors* Le Conte.

**Paromalus gilensis* Le Conte.

*Paromalus* sp. Aguascalientes, Mex.

*Saprinus pennsylvanicus* Paykull. Cotulla, Tex., May (F. C. Pratt).

*Terapus mniszechi* Marseul (E. Dugès), Mexico. Although recorded by Dugès' as a cactus insect Mr. Schwarz considers it strictly myrmecophilous.

**Acritus arizonæ* Horn.

*Camptodes cacti* Dugès.

This is a manuscript name. The species may be *C. heterocheilus* Sharp. Mexico.

**Holoparamecus pacificus* Le Conte.

**Alindria teres* Melsheimer.

*Smicrips hypocoproides* Reitter. Corpus Christi, Tex., March (W. D. Pierce).

*Hyporhagus opuntiæ* Horn. On Opuntia in Arizona (E. A. Schwarz and F. C. Bishopp).

*Hyporhagus texanus* Linell. San Diego, Tex., in decaying *Opuntia engelmanni* (E. A. Schwarz); Encinal and Hondo, Tex. (J. D. Mitchell).

*Brachytarsus* sp. Brownsville, Tex., March (C. R. Jones and F. C. Pratt).

DIPTERA.

**Ceratopogon* sp. Tucson, Ariz.

**Scatopse* sp. Tucson, Ariz.

*Hermetia chrysopila* Loew. San Antonio, Dallas, Encinal, Tex. (J. D. Mitchell and F. C. Pratt); Los Angeles, Cal., September (F. C. Pratt).

*Hermetia hunteri* Coquillett. Hondo, Encinal, Cotulla, Tex., May to October (F. C. Pratt and J. D. Mitchell).

*Cyphomyia schaefferi* Coquillett. Dallas, Tex., June.

*Microdon globosus* Fabricius. Dallas, Tex., May (C. R. Jones).

*Nausigaster unimaculata* Townsend. Cotulla, San Antonio, Tex., April (F. C. Pratt); Victoria, Tex. (J. D. Mitchell).

Reared from Opuntia.

*Volucella pusilla* Macquart. Various Texas localities: Victoria and Tivoli (J. D. Mitchell); Dallas, Corpus Christi, Cotulla, Beeville, San Antonio (F. C. Pratt).

*Volucella fasciata* Macquart. New Braunfels, Denton, Dallas, Tex., May (F. C. Pratt); Victoria, Tex., May (J. D. Mitchell); New Jersey (J. B. Smith).

**Volucella avida* Osten Sacken. Tucson, Ariz., December. In *Opuntia fulgida* and *Cereus giganteus*. (See Psyche, May, 1899.) Cotulla and San Antonio, Tex. (J. D. Mitchell); Encinal, Tex., April to June (F. C. Pratt).

*Volucella esuriens* Fabricius. At Texas localities below: Cotulla, Kerrville, Hebbronville, San Diego (F. C. Pratt); Live Oak County, San Antonio, Alice, Corpus Christi (J. D. Mitchell), March to May.

*Copestylum marginatum* Say. San Antonio, Falfurrias, Mathis, Live Oak County, Kerrville, Encinal, Cotulla, Hondo, Dallas, Tex. (various localities by J. D. Mitchell and F. C. Pratt); Los Angeles and Riverside, Cal. (F. C. Pratt).

*Hilarella decens* Townsend. Albuquerque, N. Mex., June (F. C. Pratt).
*Helicobia quadrisetosa* Coquillett. Corpus Christi, Tex., March (F. C. Pratt).
*Musca domestica* Linnaeus. San Luis Potosi, Mex., June (Rose).
In decaying fruit.
*Phorbia fusciceps* Zetterstedt. Riverside, Cal., May (D. Griffiths).
*Sapromyza vulgaris* Fitch. Riverside, Cal., May (D. Griffiths).
*Rivellia* sp. (?) Corpus Christi and San Antonio, Tex. (F. C. Pratt), March to June.
**Limosina* sp. Tucson, Ariz.
*Stictomyia longicornis* Bigot. Generally distributed in Texas and Mexico. Taken at the following localities in Texas: Victoria, Encinal, Hondo, D'Hanis, Tivoli, San Diego, Kingsville, Corpus Christi (J. D. Mitchell); Sabinal, Kerrville, San Antonio (F. C. Pratt); Brownsville (D. Griffiths), March to November. In Mexico at Durango, December (F. C. Bishopp and E. A. Schwarz).
**Nerius flavifrons* Bigot. Tucson, Ariz.

## SPECIES WHICH MERELY FREQUENT THE FLOWERS.

### COLEOPTERA.

*Carpophilus pallipennis* Say. San Antonio, Encinal, Hondo, D'Hanis, Corpus Christi, Tex., May (J. D. Mitchell); Dallas, Tex. (F. C. Pratt); Los Angeles, Cal, (F. C. Pratt), June; San Pedro and Riverside, Cal., May (D. Griffiths).
*Acmæodera tubulus* Fabricius. D'Hanis, Tex., May (J. D. Mitchell); Zavalla County, Tex., May (W. D. Hunter and F. C. Pratt).
*Acmæodera quadrivittata* Horn. El Paso, Tex., August (F. C. Pratt).
*Acmæodera pulchella* Herbst. Zavalla County, Tex., May (W. D. Hunter and F. C. Pratt).
**Lycaina discoidalis* Horn. Arizona.
*Chauliognathus scutellaris* Le Conte. D'Hanis, Tex., April (J. D. Mitchell).
*Listrus* sp. Zavalla County, Tex., May (W. D. Hunter and F. C. Pratt); Brownsville, Tex., April (C. R. Jones and F. C. Pratt).
*Euphoria kernii* Haldeman. Encinal, San Antonio, and Zavalla County, Tex., May (F. C. Pratt and D. Griffiths); Hondo, D'Hanis, and Brownsville, Tex. (J. D. Mitchell).
*Colaspoides macrocephalus* Schaeffer. D'Hanis, Tex., May (J. D. Mitchell).
*Nodonota tristis* Olivier. D'Hanis, Tex., May (J. D. Mitchell).
*Leptinotarsa haldemani* Rogers. Victoria, Tex., May (J. D. Mitchell).
Under Opuntia.
*Chrysomela auripennis* Say. Victoria, Tex., May (J. D. Mitchell).
*Luperodes brunneus* Crotch. Victoria, Tex., April (J. D. Mitchell).
*Eupogonius vestitus* Say (?). Victoria, Tex., May (J. D. Mitchell).
*Diabrotica 12-punctata* Olivier. Los Angeles, Cal., June (F. C. Pratt).
*Phyllotreta pusilla* Horn. D'Hanis, Tex., April (J. D. Mitchell).
*Bruchus* sp. Aguascalientes, Mex., December (E. A. Schwarz and F. C. Bishopp); Tucson, Ariz., May (F. C. Pratt).
*Epicauta trichrus* Pallas. Hondo and D'Hanis, Tex., May (J. D. Mitchell).

### HYMENOPTERA.

*Chrysis* sp. Victoria, Tex., April (R. A. Cushman).
*Halictus* sp. Los Angeles, Cal., June (F. C. Pratt).

*Dialictus occidentalis* Crawford. Flagstaff, Ariz., June (F. C. Pratt). At Echinocereus.

*Augochlora neglectula* Cockerell. New Mexico. At *Echinocactus wislizeni* (T. D. A. Cockerell).

*Agapostemon texanus* Cresson. New Mexico. At *Cereus polyacanthus* and *C. pendleri?* (T. D. A. Cockerell); Flagstaff, Ariz., June (F. C. Pratt).

*Perdita megacephala* Cresson. Hondo, Tex., April (J. D. Mitchell).

*Ashmeadiella cactorum* Cockerell. Santa Fe, N. Mex., on *Cactus radiosus neomexicanus* (Eng.) (T. D. A. Cockerell).

*Ashmeadiella opuntiæ* Cockerell. New Mexico, on Opuntia (T. D. A. Cockerell).

*Ashmeadiella echinocerei* Cockerell. Flagstaff, Ariz., at *Echinocereus* sp (F. C. Pratt).

*Heriades gracilior* Cockerell. New Mexico, on Opuntia (T. D. A. Cockerell).

*Lithurgus echinocacti* Cockerell. New Mexico, on *Echinocactus wislizeni* (T. D. A. Cockerell).

*Lithurgus apicalis opuntiæ* Cockerell. New Mexico. At *Opuntia arborescens* (T. D. A. Cockerell); Zavalla County and Sabinal, Tex., and Tucson, Ariz. (F. C. Pratt).

*Megachile populi* Cockerell (Syn.: *M. opuntiarum* Cockerell, *fide* Cockerell). Colorado (T. D. A. Cockerell).

*Megachile sidalceæ* Cockerell. New Mexico. On *Opuntia engelmanni* (T. D. A. Cockerell).

*Melissodes pallidicincta* Cockerell. Colorado (T. D. A. Cockerell).

*Melissodes opuntiella* Cockerell. Brownsville, Tex. (F. C. Pratt); Hondo, Tex. (J. D. Mitchell).

*Diadasia australis* Cresson. New Mexico and Colorado, on *Opuntia arborescens* (T. D. A. Cockerell); Cotulla, Hondo, D'Hanis, and Zavalla County, Tex., April (F. C. Pratt).

*D. australis opuntiæ* Cockerell. Southern California, on *Opuntia littoralis* (Eng.) (T. D. A. Cockerell); Los Angeles, Cal., June (F. C. Pratt).

*Diadasia australis rinconis* (Cockerell). New Mexico. *Opuntia engelmanni* and *O. arborescens* (T. D. A. Cockerell); Runge, Zavalla County, and Brownsville, Tex., March (F. C. Pratt); Cotulla, Tex., April (J. D. Mitchell), on *O. leptocaulis* and *O. lindheimeri;* Los Angeles, Cal. (F. C. Pratt).

*Diadasia piercei* Cockerell. Beeville, Tex. (C. L. Marlatt).

*Diadasia bituberculata* Cresson. Los Angeles, Cal.

### DIPTERA.

*Mesogramma marginata* Say. Hondo, Tex., April (J. D. Mitchell).

## SPECIES INCIDENTALLY ASSOCIATED WITH THE PLANT.

### ORTHOPTERA.

*Spongophora apicidentata* Caudell. Aguascalientes, Mexico, December (F. C. Bishopp).

* *Spongophora brunncipennis* Serville. Tucson, Ariz.

*Dichromorpha viridis* Scudder. Laredo, Tex., May (J. D. Mitchell).

*Dichopetala brevihastata* Scudder. Alice, Corpus Christi, and Maverick County, Tex., May (J. D. Mitchell and F. C. Pratt).

*Dichopetala emarginata* Brunner. Hebbronville, Tex., May (J. D. Mitchell).

*Dichopetala* sp. Encinal, Tex., April.

*Stipator nigromarginata* Caudell. Corpus Christi, Tex. (J. D. Mitchell); Alice, Encinal, and Maverick County, Tex. (J. D. Mitchell).

*Stipator haldemanni* Girard. San Antonio, Tex., April (W. D. Hunter and F. C. Pratt).

*Stipator mitchelli* Caudell. Alice and Hondo, Tex., April (J. D. Mitchell).

*Stipator pratti* Caudell. Alice, Tex., August (J. D. Mitchell).

*Stipator grandis* Rehn. Corpus Christi, Tex., August (J. D. Mitchell).

*Rehnia spinosa* Caudell. Cotulla, Encinal, and Hondo, Tex., May (F. C. Pratt); Maverick County and Hebbronville, Tex. (J. D. Mitchell).
Feeding on petal of Opuntia.

### HEMIPTERA.

**Brochymena obscura* Herrich-Schaeffer. San Antonio, Tex., November (J. D. Mitchell); Tucson, Ariz. (H. G. Hubbard).

*Anasa tristis* Say. Sabinal, Tex., December (F. C. Pratt).
Under Opuntia.

*Nysius ericæ* Schilling (Syn.: *angustatus* Uhler). San Antonio, Tex., June (E. S. Tucker).

*Ligyrocoris pseudoheræus* Barber. San Antonio, Tex., November (J. D. Mitchell).
Under Opuntia.

*Tempyra biguttula* Stål. D'Hanis, Tex., April (J. D. Mitchell).

*Cnemodus mavortius* Say. Sabinal, Tex., December (F. C. Pratt).
Under Opuntia.

*Lygæus abulus* Distant. San Antonio, Tex., September (J. D. Mitchell).
Under Opuntia.

### COLEOPTERA.

*Pasimachus californicus* Chaudoir. Encinal, Tex., April (J. D. Mitchell).

*Pasimachus depressus* Fabricius. San Antonio and Cotulla, Tex. (F. C. Pratt).

*Dicælus costatus* Lec. Encinal, Tex., April (J. D. Mitchell).

*Discoderus impotens* Le Conte. Hondo, Tex., June (J. D. Mitchell).

*Cercyon* sp. Aguascalientes, Mexico, December (F. C. Bishopp).

*Rhagodera* sp. Encinal, Tex., April (J. D. Mitchell).

**Ditoma gracilis* Sharp.

**Ditoma sulcata* Le Conte.

**Bothrideres denticollis* Dugès, MS. Mexico.

*Agrypnus sallei* Le Conte. Cotulla, Tex., May (J. D. Mitchell).

*Chalcolepidius viridipilis* Say. D'Hanis, Tex., May (J. D. Mitchell).

*Diplotaxis truncatula* Le Conte. Encinal, Tex., May (J. D. Mitchell).

*Phileurus cribrosus* Le Conte. Encinal and Hondo, Tex., April (J. D. Mitchell).

*Ataxia crypta* Say. Hondo, Tex., March (J. D. Mitchell).

*Triorophus nodiceps* Le Conte. Encinal and Cotulla, Tex., May (J. D. Mitchell).

*Eurymetopon muricatulum* Casey. Tucson, Ariz., May (F. C. Pratt).

*Emmenastus texanus* Le Conte. Encinal and Cotulla, Tex., May (J. D. Mitchell).

*Noserus emarginatus* Horn. Hondo, Tex., May (J. D. Mitchell).

*Centrioptera variolosa* Horn. Tucson, Ariz., May (F. C. Pratt).

*Centrioptera infausta* Le Conte. Cotulla, Tex. (J. D. Mitchell). Under fallen Opuntia leaves. Encinal, Tex., May.

*Eleodes tricostata* Say. Encinal, Tex., May (J. D. Mitchell).

*Eleodes texana* Le Conte. Oakville, Tex., December (J. D. Mitchell).

*Eleodes ventricosa* Le Conte. Hondo, Tex., November (F. C. Pratt).

*Eleodes armata* Le Conte. Tucson, Ariz., May (F. C. Pratt).

*Eleodes carbonaria* Say. Tucson, Ariz., May (F. C. Pratt); Cotulla, Tex. (J. D. Mitchell).

*Eleodes carbonaria* var. *soror* Le Conte. Cotulla, Tex. (J. D. Mitchell).

*Anthicus infernus* La Ferté-Sénectère. Mexico.

*Blapstinus pratensis* Le Conte. Hondo, Corpus Christi, Encinal, Cotulla, Tex., March to November (J. D. Mitchell); Hondo, Tex., November (F. C. Pratt).

**Ulosonia marginata* Le Conte.

**Cynæus angustus* Le Conte.

*Helops farctus* Le Conte. Hondo, Tex., May (J. D. Mitchell).

*Othnius senecionis* Champion. Durango, Mexico, November (F. C. Bishopp); Aguascalientes, Mex., December (F. C. Bishopp); Texas (E. A. Schwarz).

*Compsus auricephalus* Say. Hondo, Tex., April (J. D. Mitchell).

*Coleocerus marmoratus* Say. D'Hanis, Tex., May (J. D. Mitchell).

*Smicronyx spretus* Dietz. San Antonio, Tex., June (J. C. Crawford).

On Opuntia.

*Calandra remota* Sharp. "Occurs commonly in the stems of banana and prickly pear near Honolulu." (Mem. Coleoptera Hawaiian Islands, p. 183.)

**Apotrepus densicollis* Casey.

**Cossonus hubbardi* Schwarz.

## LEPIDOPTERA.

*Kricogonia lyside* Godart. Encinal, Tex., May (J. D. Mitchell).

*Pontia protodice* Boisduval. Encinal, Tex., April (J. D. Mitchell).

*Campometra impartialis* Harvey. Cotulla, Tex., April (J. D. Mitchell). Pupa found under dead Opuntia joints.

*Lineodes integra* Zeller. San Antonio, Tex., September.

On Opuntia.

"I bred this on Solanaceæ."—H. G. Dyar.

## HYMENOPTERA.

*Stomatocera rubra* Ashmead. Corpus Christi, Tex., April (F. C. Pratt).

**Pachycondyla harpax* F. Smith. Hondo, Tex., May (J. D. Mitchell).

Under dead Opuntia leaves.

*Neoponera villosa* F. Smith. Falfurrias, Tex., April (J. D. Mitchell).

Nesting in leaves of dead cacti.

*Odontomachus clarus* Roger (?). Hondo, Tex., June (J. D. Mitchell).

Crawling under dead Opuntia.

*Pseudomyrma brunnea* F. Smith. Aguascalientes, Mex., December (F. C. Bishopp); Corpus Christi, Tex. (F. C. Pratt).

*Pheidole* sp. Los Angeles, Cal., June (F. C. Pratt).

Under decaying Opuntia, carrying dipterous larvæ.

*Cremastogaster lineolata* Say. Hondo, Tex., May (J. D. Mitchell)

Under dead Opuntia leaves.

*Cremastogaster* sp. Tucson, Ariz., May (F. C. Pratt).

Attending aphis on *Opuntia versicolor* and *O. fulgida*.

*Leptothorax* sp. Victoria, Tex., April (J. D. Mitchell).

Nesting in green fruit of Opuntia.

*Dorymyrmex pyramicus* Roger var. *flavus* McCook. Los Angeles, Cal., June (F. C. Pratt).

On Opuntia fruit.

*Iridomyrmex analis* Ernest André. El Paso, Tex., May (F. C. Pratt), in Opuntia bloom; Tucson, Ariz., May (F. C. Pratt), attending aphis on *Opuntia versicolor, O. engelmanni,* and *O. fulgida.*

*Forelius maccooki* Forel. Laredo, Tex., August (J. D. Mitchell).
Eating Opuntia fruit opened by some other insect.

*Prenolepis viridula* Nylander, subsp. *melanderi* Wheeler. Victoria, Tex., March (J. D. Mitchell).
In green Opuntia fruit.

*Formica subpolita* Mayr, var. Flagstaff, Ariz., June (F. C. Pratt).
Attending aphis on Echinocereus.

*Myrmecocystus melliger* Forel, var. Brownsville, Tex., April (R. A. Cushman), on Opuntia; Hondo, Tex., May (J. D. Mitchell), under dead leaves of Opuntia; Albuquerque, N. Mex., June (F. C. Pratt), on *Opuntia arborescens.*

*Camponotus maculatus vicinus* Mayr, var. *nitidiventris* Emery. Albuquerque, N. Mex., May (F. C. Pratt).
On *Opuntia arborescens.*

*Camponotus* sp. Bee County, Tex., May (J. D. Mitchell).
Nest in root hole of dead Opuntia.

*Pycnomutilla texana* Blake. Hondo, Tex., April (J. D. Mitchell).

*Dasymutilla orcus* Cresson. Corpus Christi, Tex., August (J. D. Mitchell).

*Paratiphia* sp. Tucson, Ariz., May.

*Compsomeris 4-notata* Fabricius. Victoria, Tex., April (H. P. Wood).

*Odynerus clusinus* Cresson. San Diego, Tex., April (F. C. Pratt).

*Euglossa surinamensis* Linnæus. Brownsville, Tex., March (F. C. Pratt).
On *O. lindheimeri.*

*Eucœla* sp.

### DIPTERA.

*Atomosia puella* Wiedemann. D'Hanis, Tex., May (J. D. Mitchell).

*Epricromyia floridensis* Townsend. "Pratt-Cactus in winter."

*Notogramma stigma* Fabricius. San Antonio, Tex., June (F. C. Pratt).

*Epiplatea scutellata* Wiedemann. Corpus Christi, Tex., March (F. C. Pratt); San Antonio, Tex., March (F. C. Pratt).

*Chlorops quinquepunctata* Loew. Los Angeles, Cal., June (F. C. Pratt).

*Oscinis coxendix* Fitch. Reared at Washington, D. C., from material from unknown locality.

NOTE.—In Insect Life, vol. 3, p. 402, will be found a note on injury to *Mammillaria phellosperma* by undetermined sowbugs. Hubbard recorded two species of Gamasidæ and two of Pseudoscorpionidæ from the pulp of *Cereus giganteus.*

## BIBLIOGRAPHY OF CACTUS INSECTS.

This bibliography is intended to be complete in so far as the important records of the occurrence of insects on cactus are concerned. It does not include, however, the numerous references to the cochineal insect which are scattered throughout the general literature of entomology and many trade journals, although several of the more important special articles on this insect have been admitted. In the paper by De Nobrega will be found many references to older accounts of the cochineal insect.

1811. HUMBOLDT, A. VON.—Political essay on the kingdom of new Spain. Translation by John Black. London.
Full account of the cochineal industry in Central America.

1849. DE NOBREGA, GERARDO JOSE.—On the cultivation of cochineal. <Pharmaceutical Journal, vol. 8, pp. 342–348, 1 fig.

Covers cultivation of the nopal, rearing the insect, and methods of killing the cochineal and preparing it for sale.

1855. MARTINS, THEODOR.—Culture of the cochineal in the Canary Islands. <Pharmaceutical Journal, vol. 14, pp. 553–556.

1876. UHLER, P. R.—List of Hemiptera of the region west of the Mississippi, including those collected during the Hayden explorations of 1903. <Bul. U. S. Geol. Survey (2) No. 5, vol. 1, pp. 269–361.

1877. POPENOE, E. A.—A list of Kansas Coleoptera. <Trans. Kans. Acad. Sci., vol. 5, pp. 21–40.

*Moneilema annulatum* Say on Opuntia in Kansas.

1878. POPENOE, E. A.—Additions to the catalogue of Kansas Coleoptera. <Trans. Kans. Acad. Sci., vol. 6, pp. 77–86.

*Moneilema semipunctatum* Le Conte on Opuntia in Kansas.

1883. BLANCHARD, RAPHAËL.—Les coccidé utiles. <Bul. Soc. Zool. France, vol. 7, pp. 1–117.

An excellent account of the cochineal insect is to be found on pages 70–90.

1886. DUGÈS, EUGENE.—Metamorphoses de quelques Coléoptères Mexicains. <Ann. Soc. Ent. Belg., vol. 21, pp. 26–45, Pls. I–III.

Describes and figures larva and pupa of *Moneilema variolare* Thomson, and *Cactophagus* (*Sphenophorus*) *spinolæ* Gyllenhal. Notes on breeding in Opuntia.

1888. RILEY, C. V.—The food habits of North American Calandridæ. <Ins. Life, vol. 1, p. 199.

Mentions *Cactophagus validus* Le Conte.

1889. HORN, H. G.—(No title.) <Ins. Life, vol. 2, p. 162.

Note presented by E. A. Schwarz on *Cœnopœus palmeri*, the immature stages of which were found in stems of *Opuntia bernardina*.

1889. RILEY, C. V.—Notes on the cochineal insect <Ins. Life, vol. 1, pp. 258–259.

Rearing of predators, *Leucopis bellula* Williston, and *Drosophila quinaria* Loew. Also breeding of *Dakruma coccidivora* (=*Lætilia coccidivora* Comstock).

1891. COQUILLETT, D. W.—Another parasitic rove beetle. <Ins. Life, vol. 3, pp. 318–319.

*Maseochara valida*, parasite upon puparium of *Copestylum marginatum* Say in *O. engelmanni*, California.

1891. RILEY, C. V.—(No title.) <Can. Ent., vol. 23, p. 256.

Breeding of *Melitara prodenialis* Walker (*Megaphycis bollii*) from Opuntia "fruit" sent by Mrs. Mary Treat from Florida in 1877.

1891. RILEY, C. V., and L. O. HOWARD.—Sowbugs feeding in living plants. <Ins. Life, vol. 3, p. 402.

Sowbugs (not determined) feeding on *Mammillaria phellosperma* in California.

1891. SMITH, J. B.—Habits of *Volucella fasciata*. <Can. Ent., vol. 23, pp. 242–243.

Breeding of *Melitara prodenialis* Walker and *Volucella fasciata* Macquart in New Jersey.

1891. WILLISTON, S. W.—(No title.) <Ent. News, vol. 2, p. 162.

Breeding of *Copestylum marginatum* Say and *Volucella fasciata* Macquart.

1892. KELLOGG, V. L.—Notes on *Melitera* (sic) *dentata* Grote. <Kans. Univ. Inst., vol. 1, no. 1, pp. 39–41, 1 pl.

1893. RILEY, C. V., and L. O. HOWARD.—Insect injury to cactus plants. <Ins. Life, vol. 4, p. 345.

*Chelinidea vittigera* Uhler in Harris County, Tex.

1894. UHLER, P. R.—Observations upon the heteropterous Hemiptera of Lower California, with description of new species. <Proc. Cal. Acad. Sci., ser. 2, vol. 4, pp. 223–295.

*Narnia femorata* Stål., *N. pallidicornis* Stål., and *Chelinidea vittigera* Uhler.

1895. GILLETTE, C. P., and C. F. BAKER.—A preliminary list of the Hemiptera of Colorado. <Bul. 31, Colo. Agr. Exp. Sta.

1895. HOWARD, L. O.—A destructive scale insect new to the United States. <Ins. Life, vol. 7, p. 430.

*Dactylopius* (=*Pseudococcus*) *virgatus* Cockerell on "Jacobo" cactus at Brownsville, Tex.

1895. HUBBARD, H. G.—The oviposition of *Melitara prodenialis* Walk. <Proc. Ent. Soc. Wash., vol. 3, pp. 129–132, figs. 6, 7.

1896. MARLATT, C. L.—(No title.) <Proc. Ent. Soc. Wash., vol. 4, pp. 44, 45.

Mentions *Lobos hesperius* (=*Stylopidea picta* Uhler) on Opuntia.

1896. SCHWARZ, E. A.—(No title.) <Proc. Ent. Soc. Wash., vol. 3, p. 48.

Mentions as cactus insects *Moneilema crassum* Le Conte, *Acalles* (=*Gerstæckeria*) *turbidus* Le Conte, *A. nobilis* Le Conte, *Copestylum marginatum* Say, and an undescribed ortalid fly which breeds in the stems.

1897. COCKERELL, T. D. A.—The New Mexico bees of the genus Heriades and a new Halictus. <Ann. Mag. Nat. Hist., vol. 20, pp. 135–143.

Several cactus bees are described. Description of *Lithurgus echinocacti* Cockerell.

1898. COQUILLETT, D. W.—On the habits of the Oscinidæ and Agromyzidæ reared at the U. S. Department of Agriculture. <Bul. 10, Bur. Ent., U. S. Dept. Agr., pp. 70–79.

Rearing of *Leucopis bellula* Williston from "larvæ preying on *Coccus cacti*," Texas; also from *Coccus confusum*, New Mexico, and *Acanthococcus* sp., Mexico.

1898. COCKERELL, T. D. A.—New and little-known Hymenoptera taken by Prof. C. H. T. Townsend and Mr. C. M. Barber in New Mexico in 1898. <Ann. Mag. Nat. Hist., vol. 2, pp. 448–457.

1899. HUBBARD, H. G.—Insect fauna of the giant cactus of Arizona. Letters from the southwest. <Psyche, Suppl., May, pp. 1–13.

Notes on *Opuntia* spp. are to be found on p. 5.

1899. SCHWARZ, E. A.—Classified list of species observed by H. G. Hubbard on the giant cactus. <Psyche, Suppl., May, pp. 13–14.

1899. LINELL, M. L.—Descriptions of some new species of North American heteromerus Coleoptera. <Proc. Ent. Soc. Wash., vol. 4, pp. 180–185.

Original description of *Hyporhagus texanus* from decaying *Opuntia engelmanni* at San Diego, Tex.

1900. COCKERELL, T. D. A.—The cactus bees; genus Lithurgus. <Am. Nat., vol. 34, pp. 487–488.

1901. DUGÈS, EUGÈNE.—Catálogo de la colección de Coleopteros Mexicanos del Museo Nacional. <Cat. Mus. Nac., vol. 5, 2d ed., pp. i–iv, 1–148, pls. 12.

"*Moneilema lævithorax?* White. En los nopales, Guanajuato."

1901. SCHWARZ, E. A.—(No title.) <Proc. Ent. Soc. Wash., vol. 4, pp. 368–369, 1901.

"Exhibited pulp of giant cactus with living *Cactopinus hubbardi* Schwarz, indicating that they may live in adult condition for two years." On page 431 an additional note by Mr. Schwarz shows an increased longevity amounting to a period of four years.

1902. Dyar, H. G.—Descriptions of the larvæ of some moths from Colorado. <Proc. U. S. Nat. Mus., vol. 25, pp. 369–412.

On page 396 is a description of a larva supposed to be that of *Melitara junctolineella* Hulst. See p 27, antea.

1903. Fernald, M. E.—A catalogue of the Coccidæ of the world. <Bul. 88, Mass. Agr. Coll., pp. 360.

1903. Townsend, C. H. T.—Contribution to a knowledge of the Coleoptera of the lower Rio Grande Valley in Texas and Tamaulipas, with biological notes and special reference to geographical distribution. <Trans. Tex. Acad. Sci., vol. 5, pp. 49–101.

*Acalles* (=*Gerstæckeria*) *clathratus* Le Conte "very numerous on *Opuntia leptocaulis*, breeding in the ends of the shoots, June 5th. This species kills the ends of the shoots of this plant, the grub eating out the inside portion and forming a cell in which it transforms."

1905. Knuth, P., Otto Appel, and Ernest Loew.—Handbuch der Blütenbiologie, Leipzig.

Pages 262–263 cover Cactaceæ. The following insect records are made: *Megachile sidalceæ* Cockerell on *Opuntia engelmanni* (Bot. Jahrb., 1901, vol. 2, p. 583, New Mexico); *Diadasia* (*Eucera*) *unicornis* Cockerell, New Mexico; *Diadasia unicornis opuntiæ* Cockerell, Viereck, Proc. Acad. Sci. Phila., vol. 54, p. 728, 1902, California.

1905. Cockerell, T. D. A.—The bees of southern California. <Bul. So. Cal. Acad. Sci., vol. 4, p. 15.

*Diadasia australis opuntiæ* Cockerell, at blooms of *Opuntia littoralis* Eng.

1906. Osborn, Herbert.—Note on food habit of *Liotropis contaminatus* Uhl. <Ent. News, vol. 20, p. 177.

On fruit of *Opuntia fulgida*, Arizona; also El Paso, Tex., and Inyo Mountains, Cal.

1906. Cockerell, T. D. A.—Descriptions and records of bees, VIII. <Ann. Mag. Nat. Hist., vol. 17, pp. 222–230.

Includes several cactus species.

1906. Cockerell, T. D. A.—The North American bees of the family Anthophoridæ. <Trans. Amer. Ent. Soc., vol. 32, pp. 63–116.

*Melissodes pallidicincta* Cockerell, and *Diadasia* spp. in blooms of Opuntia.

1906. Cockerell, T. D. A.—The bees of New Mexico. <Trans. Amer. Ent. Soc., vol. 32, pp. 289–314.

*Lithurgus apicalis* Cresson, *L. echinocacti* Cockerell, and *Megachile sidalceæ* Cockerell.

1907. Busck, Aug.—New American Tineina. <Proc. Ent. Soc. Wash., vol. 8, pp. 86–99.

Original description of *Marmara opuntiella* on *Opuntia* sp., southern Texas.

1907. Cockerell, T. D. A.—A gall gnat of the prickly pear cactus. <Can. Ent., vol. 39, p. 324.

Description of *Asphondylia betheli* Cockerell.

1907. Pierce, W. D.—On the biologies of the Rhynchophora of North America. <Rept. Nebr. St. Bd. Agr., 1906, pp. 249–319, 8 pls.

Includes notes on *Acalles nobilis* Le Conte, *A. clathratus* Le Conte, and *A. turbidus* Le Conte. These species are now placed under Gerstæckeria.

1908. Banks, Nathan.—A new Tetranychus. <Proc. Ent. Soc. Wash., vol. 10, p. 36.

Original description of *T. opuntiæ* Banks.

1908. Dyar, H. G.—Description of eleven new North American Pyralidæ, with notes on a few others. <Proc. Ent. Soc. Wash., vol. 10, p. 113.

Description of *Dicymolomia opuntialis* Dyar.

1908. Felt, E. P.—Studies in Cecidomyiidæ, II. <Bul. 124, N. Y. St. Mus., pp. 307–422.

Pages 376–378 contain descriptions of *Asphondylia betheli* Cockerell, *A. opuntiæ* n. sp., and *A. arizonensis* n. sp.

1908. Griffiths, David.—The prickly pear as a farm crop. <Bul. 124, Bur. Plant Ind., U. S. Dept. Agr.

Diseases and *Tetranychus opuntiæ* mentioned.

1909. Coquillett, D. W.—A new stratiomyid from Texas. <Can. Ent., vol. 41, p. 212, 1909.

Description of *Hermetia hunteri* Coquillett.

1909. Essig, E. O.—The genus Pseudococcus in California. <Pomona Journ. Ent., vol. 1, no. 2, pp. 35–46, figs. 22–32.

Description of *Pseudococcus obscurus* on roots of *Opuntia* sp., California (p. 43).

1910. Felt, E. P.—Two new Cecidomyiidæ. <Ent. News, vol. 21, pp. 10–12.

Original description of *Cecidomyia opuntiæ,* on Italian and West Indian Opuntia in New York Botanical Gardens.

1911. Pierce, W. D.—Systematic notes and descriptions of some weevils of economic or biological importance. <Proc. U. S. Nat. Mus., vol. 42, no. 1889, pp. 155–170.

Contains a systematic treatment of the genus Gertæckeria, with descriptions of *Gerstæckeria tessellata, G. alternata, G. opuntiæ, G. fasciata,* and *G. cactophaga,* all of which are probably cactus insects.

[illegible]

[illegible] with [illegible]

[illegible] Descriptions of eleven new North American [illegible] from [illegible]

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O


COTTON PLANT ATTACKED BY BOLL WEEVIL.

*a*, Hanging dry square infested by weevil larva; *b*, flared square, with weevil punctures; *c*, cotton boll, sectioned, showing attacking weevil and weevil larva in its cell. (Original.)

62D CONGRESS }
2d Session }

SENATE

{ DOCUMENT
{ No. 305

# MEXICAN COTTON-BOLL WEEVIL

MESSAGE FROM THE
PRESIDENT OF THE UNITED STATES

TRANSMITTING

A COMMUNICATION FROM THE
SECRETARY OF AGRICULTURE
SUBMITTING A REPORT ON THE
MEXICAN COTTON-BOLL WEEVIL

WASHINGTON
1912

UNITED STATES OF AMERICA ★ GOVERNMENT PRINTING OFFICE ★

## LETTER OF TRANSMITTAL.

*To the Senate and House of Representatives:*

I transmit herewith for the information of the Congress a communication from the Secretary of Agriculture, accompanying the manuscript of a report on the Mexican Cotton-boll Weevil: A Summary of the Results of the Investigation of this Insect up to December 31, 1911. (Bulletin No. 114, Bureau of Entomology.)

The report contains valuable information of great public interest to cotton planters of this country and those depending upon the cotton-plant industry, and I cordially indorse the recommendation of the Secretary that the report be printed for distribution by Congress as well as by the department.

WM. H. TAFT.

THE WHITE HOUSE, *February 12, 1912.*

# LETTERS OF SUBMITTAL.

DEPARTMENT OF AGRICULTURE,
OFFICE OF THE SECRETARY,
*Washington, February 8, 1912.*

To the PRESIDENT OF THE UNITED STATES.

MR. PRESIDENT: I have the honor to submit herewith, for your information and that of the Congress of the United States, a bulletin entitled "The Mexican Cotton-boll Weevil: A Summary of the Results of the Investigation of this Insect up to December 31, 1911," by Messrs. W. D. Hunter and W. D. Pierce of this department. This is an elaboration of a bulletin published in 1905 and of which a special edition was ordered by Congress. Since that date the weevil has spread throughout the State of Louisiana and has entered the States of Arkansas, Mississippi, and Alabama, and threatens to spread throughout the entire cotton-growing area east of the arid regions. In the course of this eastward and northward spread, new conditions have been encountered; the habits and life history of the weevil have undergone some change, and it has met with new parasites and natural enemies. There is a great demand among the cotton planters of this country and among those dependent upon the cotton-planting industry for the information contained in this bulletin, and, in view of this fact, I respectfully recommend that this report be transmitted to Congress, together with the maps, illustrations and diagrams accompanying it, to be printed by order of Congress; and I further recommend that not less than 10,000 copies be printed for the use of this department, in addition to such number as Congress may order for the use of its Members.

I have the honor to remain, Mr. President,

Very respectfully,

JAMES WILSON, *Secretary.*

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DEPARTMENT OF AGRICULTURE.
BUREAU OF ENTOMOLOGY,
*Washington, D. C., January, 1912.*

SIR: I have the honor to transmit herewith and to recommend for publication a manuscript entitled "The Mexican Cotton-boll Weevil: A Summary of the Results of the Investigation of this Insect up to December 31, 1911," prepared by Messrs. W. D. Hunter and W. D. Pierce, of this bureau.

This manuscript contains in the briefest possible space an account of the exhaustive investigations of the Mexican cotton-boll weevil which have been conducted by this bureau for some years past. The last comprehensive bulletin on this subject was issued in 1905 and is now far out of date. There is urgent demand for information on this important pest, and this demand will undoubtedly continue as the insect invades new regions.

Respectfully,

L. O. HOWARD,
*Entomologist and Chief of Bureau.*

Hon. JAMES WILSON,
*Secretary of Agriculture.*

# PREFACE.

Early in 1905 the Bureau of Entomology published as Bulletin 51 an account of the information concerning the Mexican cotton-boll weevil which was available at that time. Since 1905 the work on the investigation of this important insect has been continued by the Bureau of Entomology and by various other agencies. As the result of this recent work certain features of the life history of the pest have received full treatment in publications of the bureau. This is the case with hibernation,[1] natural control,[2] parasites,[3] proliferation,[4] and repression.[5] Important contributions have been made by State agencies. The result has been that the original bulletin has been out of date for some time. On many topics the amount of information now available is more than double that at hand at the time the previous publication was issued. Moreover, it seems advisable that the history of the pest in the United States and an account of the losses occasioned by it should be brought up to date. For these reasons the present publication has been prepared to include all of the more important available information concerning the boll weevil. It is based upon Bulletin 51, from which many extracts have been used, and will supersede that publication.

In the nature of the case it is impossible to include all of the data which have been published with reference to certain phases of the life history of the boll weevil, such as hibernation and parasite control. In all such cases, however, the main essentials regarding these special topics have been incorporated. Persons who desire more detailed information may consult the various special publications, which are still available.

As might be supposed the accumulation of many additional data has necessarily changed some of the conclusions drawn in the earlier publication. It is to be noted, however, that these changes are generally of little consequence.

The investigation of the boll weevil was begun by the then Division of Entomology in 1895 and has been continued, more or less constantly, to the present date. The vast amount of information which has thus been accumulated is to be credited to a large number of entomologists, many of whom are now doing work in other fields, The earlier investigations of the weevil were conducted by Dr. L. O. Howard and Messrs. C. L. Marlatt, C. H. T. Townsend, E. A. Schwarz. and Frederick Mally. The State officers who have assisted materially in this work have been the entomologists of Texas, Messrs. E. D. Sanderson, A. F. Conradi, C. E. Sanborn, and Wilmon Newell; of Louisiana, Messrs. H. A. Morgan, Wilmon Newell, J. B. Garrett,

[1] Bull. 77, Bur. Ent., U. S. Dept. Agr., 1909.
[2] Bull. 74, Bur. Ent., U. S. Dept. Agr., 1907.
[3] Bull. 100, Bur. Ent., U. S. Dept. Agr., 1912.
[4] Bull. 59, Bur. Ent., U. S. Dept. Agr., 1906.
[5] Farmers' Bull. 344, U. S. Dept. Agr., 1909.

T. C. Barber, H. Dean, M. S. Dougherty, A. H. Rosenfeld, and G. A. Runner; of Oklahoma, Messrs. C. E. Sanborn and A. L. Lovett; of Arkansas, Dr. George F. Adams; of Mississippi, Messrs. Glenn W. Herrick, R. W. Harned, S. F. Blumenfeld, and R. N. Lobdell; and of Alabama, Dr. W. E. Hinds and Messrs. W. F. Turner and I. W. Carpenter. The work has been facilitated by the commissioners of agriculture of the various States, including Col. Charles Shuler, former commissioner of agriculture of Louisiana, Mr. H. E. Blakeslee, commissioner of agriculture of Mississippi, and Mr. F. W. Gist, former commissioner of agriculture of Oklahoma.

The agents of the Bureau of Entomology who have contributed to this bulletin are: Messrs. F. C. Bishopp, J. C. Crawford, R. A. Cushman, F. L. Elliott, A. F. Felt, C. W. Flynn, J. B. Garrett, W. H. Gilson, S. Goes, G. H. Harris, W. E. Hinds, W. H. Hoffman, T. E. Holloway, C. E. Hood, W. A. Hooker, R. C. Howell, C. R. Jones, B. T. Jordan, O. M. Lander, Thomas Lucas, E. A. McGregor, J. D. Mitchell, A. C. Morgan, A. W. Morrill, D. C. Parman, T. C. Paulsen, H. Pinkus, F. C. Pratt, V. I. Safro, E. A. Schwarz, J. S. Slack, G. D. Smith, H. S. Smith, C. S. Spooner, E. S. Tucker, G. N. Wolcott, and W. W. Yothers. Of these agents Dr. W. E. Hinds, who for several years was the principal assistant in the cotton boll weevil investigations of this bureau, was the most extensive contributor. To him we owe a large share of the accurate data on the life history and habits of the boll weevil. He also did a large amount of work in the preparation of Bulletin 51, upon which this publication is based. We have attempted throughout the bulletin to credit the various agents with the work for which they have been directly responsible, but in this place it must be stated that the results obtained are due to the faithful and efficient service of the whole corps of entomologists who have been associated with the writers. The work has also been greatly facilitated by the constant interest and encouragement of the chief of the bureau.

Special credit is due to Mr. E. S. Tucker for skillful preparation of the plates.

The Authors.

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# THE MEXICAN COTTON-BOLL WEEVIL: A SUMMARY OF THE INVESTIGATION OF THIS INSECT UP TO DECEMBER 31, 1911.

## ORIGIN AND HISTORY.

There is very little certainty regarding the history of the Mexican cotton-boll weevil before its presence in Texas came to the attention of the Division of Entomology in 1894. The species was described by Boheman in 1843 from specimens received from Vera Cruz, and was recorded by Suffrian in 1871 as occurring at Cardenas and San Cristobal, in Cuba. Written documents in the archives at Monclova, in the State of Coahuila, Mexico, indicate that the cultivation of cotton was practically abandoned in the vicinity of that town about the year 1848, or at least that some insect caused very great fears that it would be necessary to abandon the cultivation of cotton. A rather careful investigation of the records makes it by no means clear that the insect was the boll weevil, although there is a rather firmly embedded popular opinion in Mexico, as well as in the southern United States, that the damage must have been perpetrated by that species. So far as the accounts indicate, it might have been the bollworm (*Heliothis obsoleta* Fab.) or the cotton caterpillar (*Alabama argillacea* Hübn.).

From the time of the note by Suffrian regarding the occurrence of the weevil in Cuba in 1871, up to 1885, there has been found no published record concerning it. In 1885, however, Dr. C. V. Riley, then Entomologist of the Department of Agriculture, published in the report of the Commissioner of Agriculture a very brief note to the effect that *Anthonomus grandis* had been reared in the department from dwarfed cotton bolls sent by the late Dr. Edward Palmer from northern Mexico.[1] This is the first account in which the species is associated with damage to cotton. The material referred to was collected in the State of Coahuila, presumably not far from the town of Monclova.

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[1] The following is a copy of the original letter by Dr. Palmer:

EAGLE PASS, TEX., *Sept. 28, 1880.*

The COMMISSIONER OF AGRICULTURE.

SIR: Previous to leaving Monclova, Mexico, for this place I visited some fields planted with cotton. Seeing but few bolls of cotton, examination revealed the cause. An insect deposits its egg and the boll falls; thus some plants had only two or three, others five or six bolls, while underneath the leaves, in the shade thereof, were many that had fallen there in the moist shade to lay for the larva to hatch. Please find inclosed insects and many of the injured bolls, some newly punctured, others taken from under the plant.

Monclova, Mexico, and the surrounding country a few years ago was famous for its large supply of cotton; at this time none can be grown, owing to the destructive insect, samples of which are sent. The inhabitants would be glad to hear of a remedy, upon which matter in the future I will communicate with your department.

Your obedient servant,

EDWARD PALMER.

The specimens were sent by Dr. L. O. Howard to Mr. Henry Ulke, who transmitted them to Dr. George Horn, of Philadelphia. In turn Dr. Horn forwarded the material to Dr. Sallé, in Paris, who made the determination.

After the American occupation of Cuba the boll weevil began to attract considerable attention in that island. In 1902 it was observed that the weevil was quite injurious to cotton at Cayamas, Cuba. This place was visited by Mr. E. A. Schwarz, of the Bureau of Entomology, in the spring of 1903. He found that the native food plants of the weevil in Cuba were the "wild" or "loose" cotton (*Gossypium brasiliense*) and the native "kidney" cotton—both tree cottons.

The spread of the boll weevil in Mexico appears to have begun prior to 1892. In that year it appeared at Sabinas, State of Coahuila, and about this time or earlier it appeared at San Juan Allende, Morelos, Zaragoza, and Matamoras, Mexico. It crossed the Rio Grande at Brownsville probably before 1892. At any rate, during that year it caused considerable loss at Brownsville. In 1894 it had spread to half a dozen counties in the Brownsville region, and during the last months of the year was brought to the attention of the Division of Entomology as an important enemy of cotton. Mr. C. H. T. Townsend was immediately sent to the territory affected. His report, published in March, 1895, dealt with the life history and habits of the insect, which were previously entirely unknown, the probable method of its importation, and the damage that might result from its work, and closed with recommendations for fighting it and preventing its further advance in the cotton-producing regions of Texas. It is much to be regretted that at that time the State of Texas did not adopt the suggestion made by the Bureau of Entomology that a belt be established along the Rio Grande in which the cultivation of cotton should be prohibited, and thus the advance of the insect be cut off.[1] The events of the last few years have verified the predictions of the Division of Entomology in view of the advance made and the damage caused by the insect.

In 1895 the insect was found by the entomologists of the Division of Entomology, who continued the investigation started the year before, as far north as San Antonio and as far east as Wharton. Such a serious advance toward the cotton-producing region of the State caused the Bureau of Entomology to continue its investigations during practically the whole season. The results of this work were incorporated in a circular by Dr. L. O. Howard, published early in 1896, in both Spanish and English editions.

An unusual drought in the summer of 1896 prevented the maturity of the fall broods of the weevil, and consequently there was no extension of the territory affected. During 1896 the investigations were continued, and the results published in another circular issued in February, 1897. This circular was published in Spanish and German as well as English editions, for the benefit of the very large foreign population in southern Texas.

The season of 1897 was in many respects almost as unfavorable as that of 1896, but the pest increased its range to the region about Yoakum and Gonzales. Although this extension was small, it was exceedingly important, because the richest cotton lands in the United States were beginning to be invaded. The problem had thus become so important that Mr. C. H. T. Townsend was stationed

[1] This suggestion was brought to the attention of the General Assembly of Texas by the then Assistant Secretary of Agriculture, Dr. C. W. Dabney, who went to Austin for that purpose.

in Mexico, in a region supposed to be the original home of the insect, for several months to discover, if possible, any parasites or diseases that might be affecting it, with the object of introducing them to prey upon the pest in Texas. Unfortunately, nothing was found that gave any hope of material assistance in the warfare against the weevil.

The season of 1898 was very favorable for the insect. Investigations by the Bureau of Entomology were continued, and a summary of the work, dealing especially with experiments conducted by Mr. C. L. Marlatt in the spring of 1896, was published in still another circular. During this year the first of a long series of conventions to discuss the boll weevil was held. This meeting took place at Victoria, Tex., on October 12, and was attended by many planters, bankers, and merchants.

At this time the Legislature of the State of Texas made provision for the appointment of a State entomologist and provided a limited appropriation for an investigation of means of combating the boll weevil. In view of this fact the Bureau of Entomology discontinued temporarily the work that had been carried on through agents kept in the field almost constantly for four years, and all correspondence was referred to the State entomologist of Texas. Unfortunately, however, the insect continued to spread, and it soon became apparent that other States were threatened. This caused the work to be taken up anew by the Bureau of Entomology in 1901, in accordance with a special appropriation by Congress for an investigation independent of that which was being carried on by the State of Texas, and with special reference to the discovery, if possible, of means of preventing the insect from spreading into adjoining States.

In accordance with the provision mentioned the senior writer was sent to Texas in March, 1901, and remained in that State until December. He carried on cooperative work upon eight large plantations in the region infested by the weevil. The result of his observations was to suggest the advisability of a considerable enlargement of the scope of the work. It had been found that simple cooperative work with the planters was exceedingly unsatisfactory. The need of a means of testing the recommendations of the Bureau of Entomology upon a large scale, and thereby furnishing actual demonstrations to the planters, became apparent. Consequently, in 1902, at the suggestion of the Department of Agriculture, provision for the enlargement of the work was made by Congress. Agreements were made with two large planters in typical situations for testing the principal features of the cultural system of controlling the pest upon a large scale. At the same time the headquarters and laboratory of the special investigation were established at Victoria. The results of the field work for this year were published in the form of a Farmers' Bulletin. During this season cooperation was carried on with the Mexican commission charged with the investigation of the boll weevil in that country, which was arranged on the occasion of a personal visit of Dr. L. O. Howard to the City of Mexico in the fall of the preceding year. In November an enthusiastic convention of planters and merchants to discuss the problems was held at Dallas, Tex.

The favorable reception by the planters of Texas of the experimental field work conducted during 1902 and the increase in the

territory occupied by the pest brought about an enlarged appropriation for the work of 1903. It thus became possible to increase the number and size of the experimental fields as well as to devote more attention to the investigation of matters suggested by previous work in the laboratory. Seven experimental and demonstrational farms, aggregating 558 acres, were accordingly established in as many distinct cotton districts in Texas.

During 1903 the weevil was recorded from San Juan, Guatemala, by G. C. Champion. In this same year it was discovered that the weevils were being introduced in cottonseed into the "Laguna" district in the State of Coahuila, Mexico, but effective measures were taken by the Mexican authorities, and the infestation was suppressed. Since that time the weevil has never been recorded from this important cotton region. The year 1903 is also important as being that in which the weevil first crossed the Sabine River into Sabine and Calcasieu Parishes in Louisiana. Another feature of the year was a large boll-weevil convention held at Dallas, Tex., which established a permanent organization and issued a number of valuable circulars relating to the problem. A similar meeting was held in New Orleans on November 30, at which the governor of the State presided.

In 1904 a general realization of the great damage done by the boll weevil led to the appropriation by Congress of $250,000 for use in enabling the Secretary of Agriculture to meet the emergency caused by the ravages of the insect. It thus became possible again to increase the number of experimental farms and to pay especial attention to a number of important matters that could not be investigated previously. The large appropriation was used in part to establish the demonstration work of the department. The object of this work was to demonstrate the methods of control perfected and demonstrated previously by the Bureau of Entomology. It has gradually developed into the well-known Farmers' Cooperative Demonstration Work of the Bureau of Plant Industry.

With the advent of the weevil into Louisiana that State began energetic work against the pest. Largely through the efforts of Prof. W. C. Stubbs an extraordinary session of the legislature was convened early in 1904. The action decided upon was the establishment of the Crop Pest Commission of Louisiana, with full authority to take such a course as might be found advisable. Prof. H. A. Morgan became secretary and entomologist of the commission. In 1905 Prof. Morgan was succeeded by Mr. Wilmon Newell, who continued the cooperative investigations with the Bureau of Entomology throughout the period of his services in Louisiana, which extended to January 31, 1910.

During 1904 two conventions were held at Shreveport, La. The first discussed especially the local features of the problem, while the second, which was held in November, was national in its scope. It was attended by delegates from most of the Southern States.

The year 1904 witnessed an extensive dispersion of the weevil into new regions in Texas and Louisiana. During this year, Dr. O. F. Cook, of the Bureau of Plant Industry, found the weevil thoroughly established in Alta Vera Paz, Guatemala.

At the beginning of 1905 the laboratory of the bureau was moved from Victoria to Dallas, Tex., where it has since remained. The

observations on the activities of the boll weevil in this year were considerably limited, owing to restrictions on travel imposed by the yellow-fever quarantine. The insect was found, however, at Mazatlan, State of Sinaloa, on the Pacific coast of Mexico, on March 20, 1905.

In 1906 the weevil spread extensively to the west in Texas, a considerable distance northward into Oklahoma, into Arkansas, and almost to the Mississippi River in Louisiana. During this season Mr. M. T. Cook recorded the weevil from Santiago de las Vegas, Cuba, in addition to places previously recorded.

The year 1907 marked the crossing of the Mississippi River into the State of Mississippi. There was a corresponding movement to the north, but none to the west. A very severe setback, caused by climatic conditions, occurred in the northern and western parts of the infested territory in November, 1907.

In 1908 the most noticeable advances were made into Mississippi and Arkansas. By this time a considerable part of the Mississippi Delta region of Louisiana had become infested.

In the spring of 1909 preparations were made for the establishment of a laboratory at Tallulah, La. The main object of this laboratory has been the accumulation of data concerning the local features of the weevil problem in the region where the greatest damage is certain to occur. Cold weather in the winter of 1908–9 again checked the boll weevil so completely that it did no appreciable damage in Oklahoma and the greater part of Texas during 1909. The checking of the insect was enhanced by the very unusual heat of July and August. However, there were enough weevils in the Red River Valley to give rise to a considerable movement into Arkansas and to a remarkable eastward movement in southern Mississippi which ended with a total advance of 120 miles eastward. This carried the insect to within 6 miles of the Alabama border. At the same time the decided climatic control of the season held the weevils in check in northern Louisiana so that the total advance in the Delta was little more than 20 miles northeastward. The year 1909 closed with an exceptionally cold December which greatly reduced the numbers of the weevil in extreme northern Louisiana and in Arkansas, Oklahoma, and northern Texas.

The winter of 1909–10 was probably more disastrous for the weevil than any it had previously experienced in this country. It was shown by examinations made in June and July, 1910, that the weevil had lost a very wide belt of territory in western Texas and that there was less than 1 per cent infestation in one-third of the infested region of Oklahoma and Texas. The reduction was also very pronounced in northern Louisiana and in the Mississippi Delta. In August it was found that there had been some recovery of lost territory, but there were still several thousand square miles of formerly infested territory in Oklahoma which the weevil had been unable to regain. There were slight gains in western Texas in the vicinity of Abilene late in the season and rather pronounced gains in the Delta region of Arkansas and in the hills of northern Mississippi and eastward through southern Mississippi and Alabama to the border of Florida. On account of the general scarcity of weevils the total amount of damage done during 1910 was less than had been experienced for several preceding years.

An early frost on October 29, 1910, throughout all but the coast regions of the infested territory, caused the death of all but a very small fraction of the fall-bred weevils, and consequently the season of 1911 started with a low infestation. The general defoliation by the leaf worm, however, reduced the available food supply and caused a general dispersion, which enabled the weevils to regain considerable lost ground in Texas and Oklahoma, to make remarkable gains in Arkansas, Mississippi, and Alabama, and to invade Florida.

## DISTRIBUTION.

The territory covered by the boll weevil at the end of the year 1911 (see fig. 1) included the southeastern half of the cotton section of Texas, the southeastern corner of Oklahoma, the southern three-

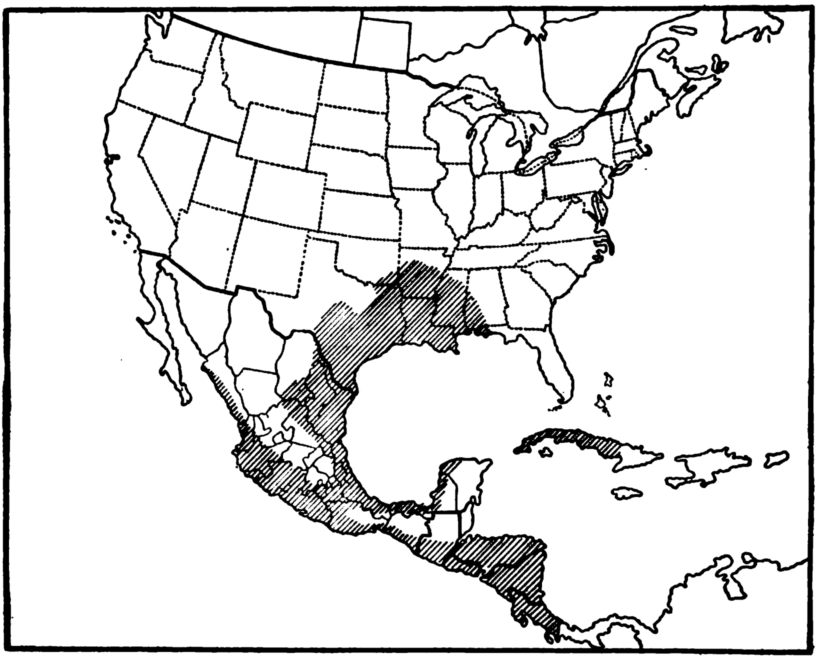


FIG. 1.—Map showing the distribution of the cotton-boll weevil on January 1, 1912. (Original.)

fourths of Arkansas, all of Louisiana, the southern three-fourths of Mississippi, the southwestern corner of Alabama, and the western portion of Florida. In addition to these States the weevil is found throughout Mexico in the cotton-growing region of both the Atlantic and Pacific coasts with the exception of certain mountain regions. Foremost among the excepted regions is that known as the Laguna district in the vicinity of Torreon, Mexico. The weevil has not been recorded from any part of Yucatan excepting the western coast, although it may occur on tree cottons throughout this region. It has not been recorded from British Honduras, but is known to occur throughout the cotton regions of Guatemala and in Costa Rica. There is little doubt but that it also extends into other Central American Republics, although no definite records have ever been

made. The five western States of Cuba are infested, and possibly the weevil is to be found throughout the entire island. It has not been found in any of the other West Indian Islands.

## LOSSES DUE TO THE BOLL WEEVIL.[1]

Various estimates of the loss occasioned to cotton planters by the boll weevil have been made. In the nature of the case such estimates must be made upon data that are difficult to obtain and in the collection of which errors must inevitably occur. There is, of course, a general tendency to exaggerate agricultural losses as well as to attribute to a single factor damage that is the result of a combination of many influences. Before the advent of the boll weevil into Texas unfavorable weather at planting time, summer droughts, and heavy fall rains caused very light crops to be produced. Now, however, the tendency is everywhere to attribute all of the shortage to the weevil. Nevertheless, the pest is undoubtedly the most serious menace that the cotton planters of the South have ever been compelled to face, if not, indeed, the most serious danger that ever threatened any agricultural industry. It was generally considered, until the appearance of the pest in Texas, that there were no apparent difficulties to prevent an increase in cotton production that would keep up to the enlarging demand of the world until at least twice the present normal crop of about 12,000,000 bales should be produced. Now, however, in the opinion of most authorities, the weevil has made this possibility somewhat doubtful, although the first fears entertained in many localities that the cultivation of cotton would have to be abandoned have generally been given up. An especially unfavorable feature of the problem is in the fact that the weevil reached Texas at what would have been, from other considerations, the most critical time in the history of the production of the staple in the State. The natural fertility of the cotton lands had been so great that planters had neglected such matters as seed selection, varieties, fertilizers, and rotation, that must eventually receive consideration in any cotton-producing country. In general, the only seed used was from the crop of the preceding year, unselected, and of absolutely unknown variety, and the use of fertilizers had not been practiced at all. Although it is by no means true that the fertility of the soil had been exhausted, nevertheless, on many of the older plantations in Texas the continuous planting of cotton with a run-down condition of the seed combined to make a change necessary in order that the industry might be continued profitably.

In 1905 Prof. E. D. Sanderson[2] made a very careful estimate of the damage done by the boll weevil in Texas for the six years ending with 1904. During this period he found that there had been an average annual decrease due to the boll weevil of 43 per cent, amounting to 0.182 bale per acre a year in the infected territory.

Prof. Sanderson found that in 1899 the 18 counties infested at that time showed a decrease of 0.135 bale per acre, of which it was considered that 150,000 bales were chargeable to the weevil. In 1900 the great storm of September complicated matters so that no reliable estimate of injury could be made. In 1901 the general conditions

[1] The following paragraph is modified from Bul. No. 51, Bureau of Entomology, pp. 21-25.
[2] The Boll Weevil and Cotton Crop of Texas, published by the Texas Department of Agriculture.

throughout the State were unfavorable to the cotton crop, resulting in a reduction of 0.05 bale per acre for the uninfested portion of the State. The weevil loss was estimated at 100,920 bales. In 1902 the 32 counties infested produced 0.28 bale per acre. The loss chargeable to the boll weevil was 200,000 bales. In 1903 the 49 counties infested yielded 0.23 bale per acre, as against an average of 0.43 bale during years previous to infestation, which was interpreted to show a loss of 500,000 bales due to the weevil. In 1904, 69 counties were infested. These showed a loss of 0.22 bale per acre. This meant, after deducting the losses due to the bollworm and other causes, a loss of 550,000 bales due to the boll weevil. In these estimates the losses for the period from 1899 to 1904 amounted to 1,725,000 bales.

The weevil was in Texas from 1899 to 1904, but had not caused any appreciable damage in Louisiana during that period. The statistics of production and acreage of the two States for these years show clearly the effect of the weevil on the crop.

Table I.—*Comparison of cotton production and acreage in Texas and Louisiana in equivalents of 500-pound bales.*

| Year. | Texas. | | Louisiana. | |
|---|---|---|---|---|
| | Acreage. | Crop. | Acreage. | Crop. |
| | *Acres.* | *Bales.* | *Acres.* | *Bales.* |
| 1899 | 6,642,309 | 2,609,018 | 1,179,156 | 700,352 |
| 1900 | 7,041,000 | 3,438,386 | 1,285,000 | 705,767 |
| 1901 | 7,745,100 | 2,502,166 | 1,400,650 | 840,476 |
| 1902 | 8,006,546 | 2,498,013 | 1,662,567 | 882,073 |
| 1903 | 8,129,300 | 2,471,081 | 1,709,200 | 824,965 |
| 1904 | 8,704,000 | 3,030,433 | 1,940,000 | 893,193 |

It will be seen that while the acreage in Texas and Louisiana increased at about the same proportion the crop in Texas decreased annually for the six years ending with 1904 (with two exceptions—1900 and 1904), while the crop in Louisiana increased annually (with one inconsiderable exception, in 1903). That the boll weevil prevented Texas from keeping pace with Louisiana during this period will be admitted by all. The exceptional years, 1900 and 1904, in which the production in Texas did not decrease, were those in which the conditions for the cotton plant were unusually favorable. Moreover, it is to be noted that in the first of these two years the pest had not reached far into the most productive counties.

Further indications of the amount of weevil damage are available from the statistics of production per acre, as shown by Table II:

Table II.—*Average yield per acre of cotton by five-year periods in 500-pound bales.*

| Years. | Texas. | Louisiana. | Arkansas. | Oklahoma. | Mississippi. |
|---|---|---|---|---|---|
| | *Bale.* | *Bale.* | *Bale.* | *Bale.* | *Bale.* |
| 1879 | 0.39 | 0.58 | 0.58 | 0.48 | 0.45 |
| 1889 | .37 | .51 | .40 | .48 | .40 |
| 1893–1897 | [1] .38 | .52 | .45 | .52 | .43 |
| 1898–1902 | [1] .39 | .52 | .45 | .47 | .40 |
| 1903–1907 | [1] .34 | [1] .40 | [1] .40 | [1] .47 | .44 |
| 1906–1910 | [1] .32 | [1] .29 | [1] .37 | [1] .35 | [1] .40 |

[1] During these periods the weevil has caused more or less damage to the crop.

At 13 cents a pound for lint (average price in 1909) the 1908–1910 average yields would mean an average loss from the average yield of 1893-1897 of the following amounts per acre:

| | |
|---|---|
| Texas | $3.90 |
| Louisiana | 15.25 |
| Arkansas | 5.20 |
| Oklahoma | 11.05 |
| Mississippi | 1.95 |

Messrs. Norden & Co., of New York, have made a conservative estimate of the average annual loss in the various States, as follows:

| | Per cent. |
|---|---|
| Texas, about | 15 |
| Louisiana | 15 |
| Arkansas | 15 |
| Mississippi | 21 |

The Bureau of Statistics of this department estimated the losses to the cotton crop in 1909 from various causes as shown below:[1]

TABLE III.—*Amount of injury to cotton crop of 1909 due to various causes.*

| State. | Loss in seed cotton per acre from— | | | | | | |
|---|---|---|---|---|---|---|---|
| | Climatic conditions. | Boll weevil. | Boll-worm. | Other insects. | Plant diseases. | Miscellaneous causes. | Total. |
| | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* |
| Arkansas | 112.2 | 21.5 | 2.5 | 0.7 | 14.4 | 0.7 | 152.0 |
| Louisiana | 38.8 | 148.8 | 8.5 | 1.3 | 11.0 | 1.4 | 209.8 |
| Mississippi | 103.3 | 14.1 | 8.0 | 0.7 | 18.8 | 3.1 | 148.0 |
| Oklahoma | 147.3 | 11.0 | 3.7 | 0.4 | 2.2 | 3.4 | 168.0 |
| Texas | 100.4 | 37.6 | 8.7 | 0.0 | 7.7 | 0.6 | 155.0 |
| Average of infested region | 100.4 | 46.6 | 6.2 | 0.6 | 10.8 | 1.8 | 166.4 |

According to this estimate, the boll weevil was responsible for 28 per cent of the loss in the five infested States and 14.9 per cent of the loss in the United States. This loss was estimated as 1,267,000 bales of 500 pounds, which, at the current price of cotton in 1909, would be worth $88,056,500. Although the estimate of the Bureau of Statistics may be high, it was based upon the reports of numerous trained observers throughout the infested territory.

Frequently misconceptions arise regarding the manner in which the weevil has affected cotton production in Texas. This is due to the fact that the total crop of the State has been maintained more or less regularly since the advent of the pest. In order to obtain exact information on this point we must examine the statistics of production in different parts of the State.[2]

It is necessary to divide the State into three areas. These are eastern, central, and western Texas. The divisions are made in accordance with variations in normal annual precipitation and other factors. Eastern Texas as used in this bulletin is bounded on the west by a line running practically north and south from the western

[1] Crop Reporter, vol. 12, No. 12, p. 94, December, 1910.

[2] The following four paragraphs and table are extracted, with a few modifications, from Circular No. 122, Bureau of Entomology, pp. 5–8.

line of Lamar County to the western line of Brazoria County. In this region the rainfall is 45 inches per year or more. It comprises the counties listed below.[1] Practically the whole area is covered with forests. It covers 40,180 square miles. Central Texas comprises a broad belt from the Gulf to the Red River, beginning on the west with the limit of the belt of 32 inches normal annual rainfall, and extends eastward to the line just described as defining the western boundary of the eastern Texas area. Central Texas consists of 45 counties[2] and comprises 38,868 square miles.

It is for the most part prairie country, although there are wooded valleys and occasional strips of timbered uplands. Western Texas comprises the remainder of Texas, beginning with the line marking the western limit of the area of 32 inches normal annual precipitation. It is largely a prairie region, though wooded valleys are numerous. Another factor in differentiating western Texas from central Texas is the increased elevation.

A careful study has been made of the manner in which the weevil has affected the production of cotton in the three regions mentioned. Use has been made of the Census records of production from 1899 to 1910, a period of 12 years, as shown in Table IV:

TABLE IV.—*Eastern, central, and western Texas cotton production compared, 1899–1910 from United States Census.*

[500-pound bales.]

| Years. | Eastern. | | Central. | | Western.[3] | |
|---|---|---|---|---|---|---|
| | Bales. | Proportion of Texas crop. | Bales. | Proportion of Texas crop. | Bales. | Proportion of Texas crop. |
| | | *Per cent.* | | *Per cent.* | | *Per cent.* |
| 1899 | 637,872 | 22.44 | 1,633,618 | 62.61 | 337,528 | 12.94 |
| 1900 | 811,413 | 23.59 | 1,892,669 | 55.04 | 734,304 | 21.36 |
| 1901 | 633,620 | 25.32 | 1,448,872 | 57.90 | 419,674 | 16.77 |
| 1902 | 736,660 | 29.48 | 1,332,487 | 53.34 | 428,866 | 17.17 |
| 1903 | 545,288 | 22.06 | 1,242,654 | 50.28 | 683,139 | 27.64 |
| Average, 1899–1903 | 672,970 | 24.88 | 1,510,060 | 55.85 | 520,702 | 19.26 |
| 1904 | 720,671 | 22.91 | 1,700,224 | 54.15 | 724,475 | 23.07 |
| 1905 | 329,523 | 12.96 | 1,414,115 | 55.63 | 798,294 | 31.40 |
| 1906 | 672,497 | 16.11 | 2,213,863 | 53.03 | 1,287,846 | 30.85 |
| 1907 | 343,328 | 14.92 | 1,218,143 | 52.95 | 738,708 | 32.11 |
| 1908 | 515,038 | 13.50 | 1,980,766 | 50.60 | 1,318,681 | 33.68 |
| 1909 | 474,311 | 18.80 | 1,362,096 | 53.99 | 686,404 | 27.20 |
| 1910 | 645,158 | 21.15 | 1,677,688 | 55.02 | 726,553 | 23.83 |
| Average, 1904–1910 | 528,647 | 17.19 | 1,652,414 | 53.62 | 797,280 | 28.88 |

In eastern Texas the production for five years ending with 1903 averaged 24 per cent of the total crop of Texas. During the same series of five years western Texas averaged 19 per cent of the total

[1] Red River, Bowie, Franklin, Titus, Morris, Cass, Wood, Camp, Upshur, Marion, Harrison, Smith, Gregg, Cherokee, Rusk, Panola, Nacogdoches, Shelby, San Augustine, Sabine, Angelina, Trinity, San Jacinto, Polk, Tyler, Jasper, Newton, Liberty, Hardin, Orange, Jefferson, Chambers Galveston, Lamar, Delta, Hopkins, Rains, Van Zandt, Henderson, Freestone, Anderson, Leon, Houston, Madison, Waller, Grimes, Walker, Montgomery, Harris, Fort Bend, and Brazoria.

[2] Central Texas counties: Cooke, Grayson, Fannin, Denton, Collin, Hunt, Tarrant, Dallas, Rockwall, Kaufman, Johnson, Ellis, Bosque, Hill, Navarro, McLennan, Limestone, Bell, Falls, Williamson, Milam, Robertson, Brazos, Travis, Lee, Burleson, Washington, Hays, Bastrop, Caldwell, Fayette, Colorado, Austin, Guadalupe, Gonzales, Lavaca, Wharton, Dewitt, Goliad, Victoria, Jackson, Refugio, Calhoun, Matagorda, and Aransas.

[3] Including counties grouped by Census under "All other."

crop. For the seven years ending with 1910 the eastern Texas production dropped to 17 per cent of the total crop of the State, while the production in western Texas advanced to 28 per cent of the total crop of the State. In other words, the portion of the Texas crop produced in one area has decreased 21 per cent, and in the other it has increased 53 per cent. This increase in the west, where the dry climate reduces the boll-weevil injury, served to offset the loss in eastern Texas and thus accounts to a great extent for the fact that the total crop of the State has not fallen off.

Mr. F. W. Gist, of the Bureau of Statistics of this department, has made a very careful study to determine the center of cotton production in Texas for each year from 1899 to 1908. As would be supposed from the figures that have been given, it was found by Mr. Gist that the center of production had moved considerably to the westward. In fact, this center moved from 30.78 miles east of the ninety-seventh meridian in 1899 to 19.14 miles west of this meridian in 1908. This was a westward movement of practically 50 miles. The center of production in 1899 was on a line passing north and south through the eastern Cortion of Grayson pounty, in Texas. In 1908 the center had moved to a line passing parallel with the other through the western portion of Cooke County, in Texas. These statements may be illustrated by the following map (fig. 2).

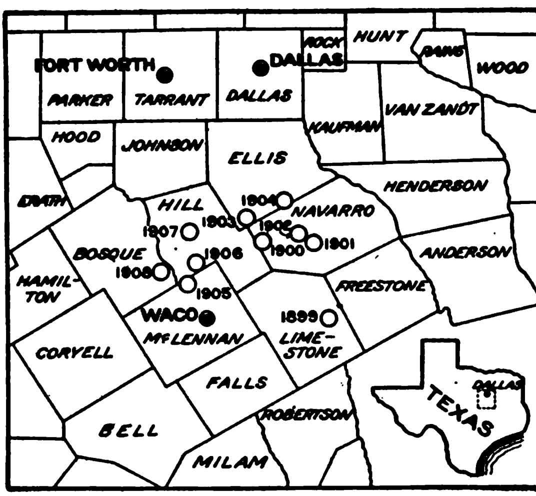



FIG. 2.—Map of portion of Texas, showing movement of the center of cotton production westward. (Original.)

The statistics which have been given show the entire fallacy of attempting to estimate the seriousness of the boll-weevil problem by considering only the total crop which has been produced in Texas for some years past. It is absolutely necessary in estimating the damage that is likely to be done in any certain region to find the portion of Texas in which the climatic and other conditions are most like those in the region that is being considered. In Texas there are several very distinct boll-weevil problems due to local conditions, exactly as there are numbers of distinct agricultural provinces. The future of the boll weevil in the eastern part of the United States can not be foretold unless the manner in which the insect has affected the portion of Texas which is most like the eastern part of the belt is considered. An investigation of this matter will show that the eastern part of Texas is the only part of the State which is like the eastern portion of the cotton belt in the climatic and other features which react upon the boll weevil. This is especially the case with

reference to precipitation, the presence of timber, and temperature. It is clear, therefore, that the only criterion by which to judge the future damage of the weevil is the effect it has exerted on production in eastern Texas, where, as has been shown, there has been a considerable decrease in production.

## INDIRECT LOSSES CAUSED BY THE BOLL WEEVIL.

The foregoing discussion has dealt altogether with the direct losses caused by the boll weevil, but it is to be noted that there are certain indirect losses which must be considered. It is not alone the farmers who are affected. The reduction in the size of the cotton crop immediately affects the ginning and oil-mill industries in which large amounts of money are invested. The railroads, banks, and merchants are also concerned. In fact, the disturbance extends throughout the community. In the case of many parishes in Louisiana one of the first results of the invasion of the boll weevil has been the reduction in the assessed valuation of farm lands. In all regions, for at least a short time, the price of farm properties has been reduced. Likewise in many localities the invasion of the insect has caused the exodus of large numbers of tenants and even of landlords. In the former case landowners have found themselves without the labor to run their places. Losses due to such disturbances can not be estimated, but it is safe to say that they reach an aggregate amount at least equal to the direct losses which are caused.

## COMPENSATIONS FOR LOSSES CAUSED BY THE BOLL WEEVIL.

In spite of the great losses caused by the boll weevil it must be recognized that certain compensations are returned. The insect forces a diversification of crops. There is no doubt that there is a tendency to place too much dependence in the South upon the cotton crop. When the ravages of the boll weevil reduce the size of this crop materially or make production of a cotton crop hazardous, the farmers must change their system of cropping materially. This results directly in diversification and animal husbandry, and thus tends toward a more logical and profitable system of agriculture. Of course it would be much better if this change could be brought about by less revolutionary means and with less loss than is caused by the boll weevil. The tendency for many years has been toward diversification, which was certain to come in time. The boll weevil has undoubtedly hastened it and has thus in a broad sense offset, to a certain degree, some of the direct losses which it has caused. It is to be noted, however, that in many cases this forced and, in one sense, premature diversification of crops has resulted disastrously. In some localities extensive and rapid growth has taken place in fruit raising and market gardening. In some of these instances the new industries have developed with abnormal rapidity and without the proper foundation. This was the case in extensive plantings of potatoes made in 1909 by the cotton planters of Avoyelles Parish, La. The result has been that unless carefully managed the new lines of farming have failed and there has been a tendency to return to the cultivation of cotton.

The boll weevil also tends to eliminate the indifferent and unprogressive farmer. He is driven either to the city or to some other locality.

In this way the weevil works toward the production of a better class of farmers. Of course, no community favors a reduction in the number of inhabitants. It would prefer that the inefficient remain and be improved by education or otherwise. This effect of the invasion of the boll weevil, therefore, can not generally be looked upon as a benefit.

## PROSPECTS.

The rapid spread of the boll weevil in the past few years and its apparent adaptability to most of the conditions prevalent in the cotton region of the United States indicate that it will ultimately be able to exist in all except the semiarid portions of the entire cotton-growing country. In order better to estimate the probable movement in the future, we present Table V to illustrate its progress since the year 1892:

TABLE V.—*Annual movement of the boll weevil in the United States.*

| Year. | Weevil advance. | | | | | | | Total movement. | Total area infested. |
|---|---|---|---|---|---|---|---|---|---|
| | Texas. | Louisiana. | Oklahoma. | Arkansas. | Mississippi. | Alabama. | Florida. | | |
| | *Sq. mi.* | *Sq. mi.* | *Sq. mi.* | *Sq. mi.* | *Sq. mi.* | *Sq. mi.* | *Sq. mi.* | *Sq. mi.* | *Sq. mi.* |
| 1892 | 1,400 | | | | | | | 1,400 | 1,400 |
| 1893 | 7,400 | | | | | | | 7,400 | 8,800 |
| 1894 | 10,300 | | | | | | | 10,300 | 19,100 |
| 1895 | 7,900 | | | | | | | 7,900 | 27,000 |
| 1896 | [1] 7,300 | | | | | | | [1] 7,300 | 19,700 |
| 1897 | 9,600 | | | | | | | 9,600 | 29,300 |
| 1898 | 7,200 | | | | | | | 7,200 | 36,500 |
| 1899 | 6,600 | | | | | | | 6,600 | 43,100 |
| 1900 | 6,600 | | | | | | | 6,600 | 49,700 |
| 1901 | 6,700 | | | | | | | 6,700 | 56,400 |
| 1902 | 11,600 | | | | | | | 11,600 | 68,000 |
| 1903 | 11,700 | 300 | | | | | | 12,000 | 80,000 |
| 1904 | 39,600 | 7,300 | | | | | | 46,900 | 126,900 |
| 1905 | 17,000 | 3,400 | | | | | | 20,400 | 147,300 |
| 1906 | 22,600 | 9,300 | 4,200 | 500 | | | | 36,600 | 183,900 |
| 1907 | | 5,000 | 8,200 | 7,800 | 500 | | | 21,500 | 205,400 |
| 1908 | | 5,700 | 1,500 | 6,500 | 4,800 | | | 18,500 | 223,900 |
| 1909 | | 9,800 | 1,900 | 7,500 | 10,700 | | | 29,900 | 253,800 |
| 1910 | 1,400 | | [1] 6,500 | 1,900 | 13,500 | 3,900 | | 14,200 | 268,000 |
| 1911 | [1] 21,000 | | [1] 3,000 | 9,700 | 11,000 | 5,400 | 1,400 | 3,500 | 271,500 |
| Total | 139,300 | 40,800 | 6,300 | 31,900 | 40,500 | 9,300 | 1,400 | 271,500 | |

[1] These figures indicate losses instead of gains.

A summary of Table V in three-year periods is given below:

TABLE VI.—*Average annual rate of boll-weevil movement.*

| Three-year periods. | Total movement. | Yearly average. | Average of averages. |
|---|---|---|---|
| | *Sq. miles.* | *Sq. miles.* | *Sq. miles.* |
| 1892–1894 | 19,100 | 6,366 | |
| 1895–1897 | 10,200 | 3,400 | |
| 1898–1900 | 20,400 | 6,800 | 5,522 |
| 1901–1903 | 30,300 | 10.100 | |
| 1904–1906 | 103,900 | 34,633 | |
| 1907–1909 | 69,900 | 23,300 | 22,677 |
| | 253,800 | | 14,099 |

At the end of 1910 the total area infested was 268,000 square miles, a net gain of 14,200 square miles over 1909. Including the year 1910, the average rate of movement in the United States beginning with

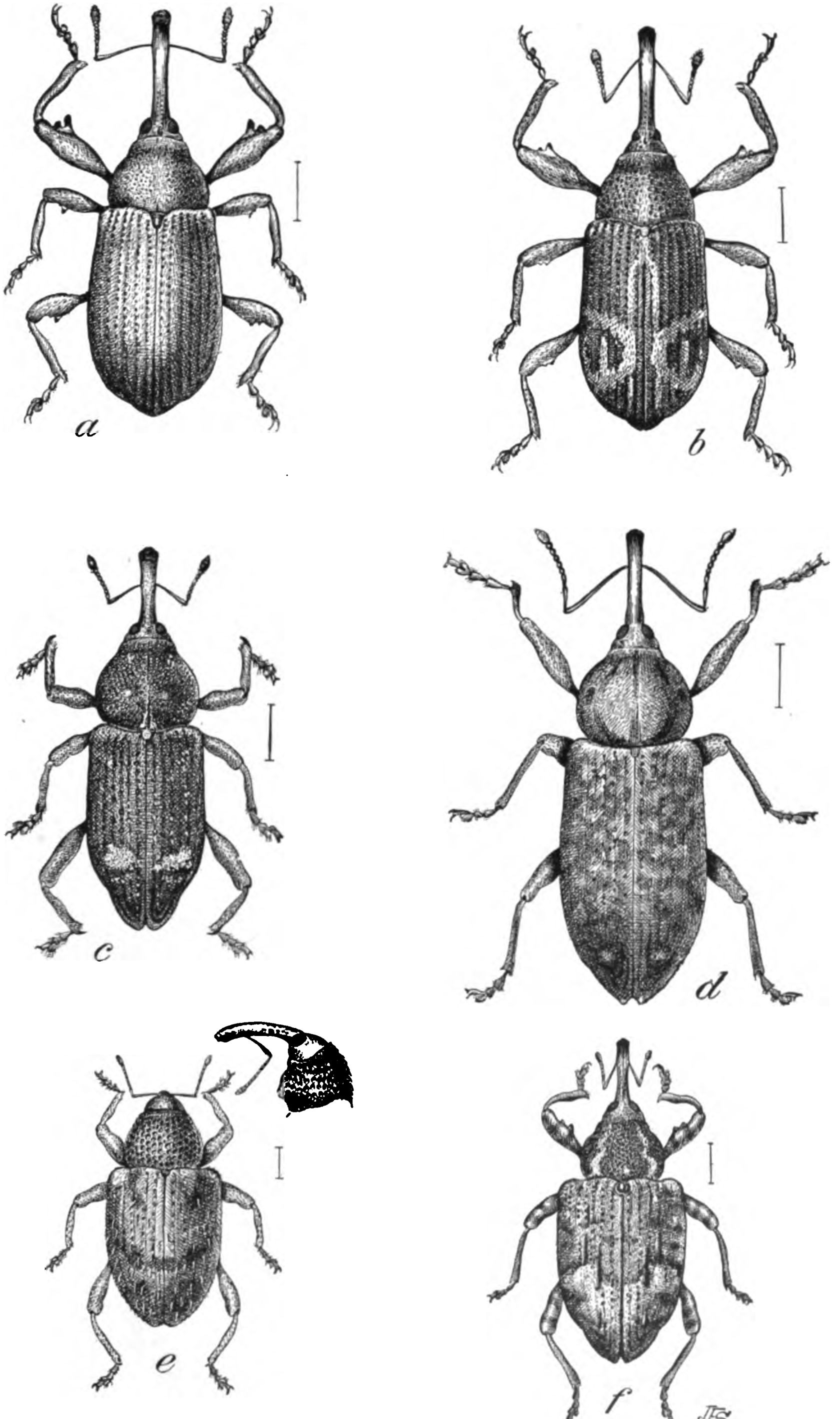
1904 has been 27,000 square miles a year, with 402,000 square miles of cotton-producing area yet free. It is therefore reasonable to estimate that it will take at least 15 years before the entire cotton region of this country can become infested.

It is evident, however, that the weevil will find certain definite checks in the cotton-growing regions of this country. Among the more important of these checks are (1) dryness, (2) low winter temperatures, (3) altitude, and (4) such combinations of these factors as tend to form definite life zones. The possible effects of these factors will be discussed separately.

Dryness is the most important check the boll weevil experiences. The insect has repeatedly advanced into western Texas, but has invariably been prevented from gaining a foothold by the dry climate of that region. Occasional wet seasons have resulted in apparent gains in that quarter, but they have been nullified by the recurrence of normal years. The extremely dry conditions in Texas, Oklahoma, and Arkansas during the summers of 1909 and 1910 had a remarkable effect upon the weevil. Combined with the very severe winters, these dry summers practically excluded the weevils from the western half of the infested region of Texas and most of the infested region in Oklahoma. The damage done in these regions for two seasons has occurred only after the breaking of the intense summer heat. The occasional occurrence of a dry summer, however, does not give any promise of future immunity from the boll weevil, because its tendency to disperse in the fall in all directions enables it to regain any ground which it might lose during such a season. It is also important to note that the practice of irrigation in dry regions may counteract the effects of the lack of precipitation and enable the weevil not only to maintain itself, but to cause considerable damage.

The low temperatures of the winters of 1907, 1908, and 1909 had a very pronounced effect upon the numbers of the weevil in the following years. An analysis of the minimum temperatures reached in the regions where the weevils were most affected indicates that such control was the result of a temperature of 12° above zero. In some places where this temperature was reached there were earlier low temperatures which may have forced the weevils into considerably heavier shelter than they would have selected normally. This apparently enabled the weevils to survive even a temperature of 5° above zero. Although the information at hand is rather incomplete, we can nevertheless hold out some hope that regions having a minimum temperature of from 5° to 10° above zero will have little trouble from the boll weevil. In later sections of this bulletin we will show how even higher minimum temperatures can greatly reduce the weevil damage of the following year. The weakness of predictions of this kind is that they do not take into account the fact that the weevil is rapidly adjusting itself to changed conditions and that eventually the result of natural selection will be a class of weevils which can withstand greater vicissitudes than those of the present.

The extremely slow progress into western Texas might be explained on the basis of altitudes. So far, the weevil has not established itself at an altitude above 2,000 feet. It may be possible that this altitude is its extreme limit. Again, there is danger in this assumption,



THE BOLL WEEVIL AND INSECTS OFTEN MISTAKEN FOR IT.

*a*, The cotton boll weevil, *Anthonomus grandis*; *b*, the mallow weevil, *Anthonomus fulvus*; *c*, the southern pine weevil, *Pissodes nemorensis*; *d*, the cottonwood-flower weevil, *Dorytomus mucidus*; *e*, *Conotrachelus erinaceus*; *f*, the pecan gall weevil, *Conotrachelus elegans*. (Original.)

because the boll weevil has shown considerable adaptability in the past and may be able to adapt itself to higher altitudes than it has yet reached.

With regard to the possible relation between life zones and the distribution of the weevil it is to be said that at present the infested territory includes the tropical regions of Cuba, Central America, and Texas, and a considerable part of the Austroriparian Zone of the Lower Austral Region in the other Southern States. It is interesting to note that the weevil has not yet succeeded in establishing itself in the Upper Sonoran Zone of the Upper Austral Region of either Mexico or western Texas. It has invaded, or at least surrounded, two isolated areas of the Carolinian Zone of the Upper Austral Region in Oklahoma and Arkansas. Considerable cotton is grown in western Texas, in the Upper Sonoran Zone. There also exist in Arkansas, southern Missouri, Tennessee, northern Georgia, northern South Carolina, western North Carolina, and Virginia large regions of cotton-producing territory included in the Carolinian Zone. It is possible that the boll weevil will be unable to establish itself permanently beyond the limits of the Lower Austral Zone and this would exclude it from the regions just mentioned.

As a matter of fact, the effects of climatic conditions upon the weevil are so powerful that there may be occasional diminution in the serious attacks from the insect in the moist regions, such as was experienced in the summer of 1911. The season of 1911 was unusual in Louisiana and Mississippi, starting with severe cold in January, which cut down the emergence from hibernation to 0.5 per cent, and continuing with a very unusual drought. Such conditions are not often experienced, and we may usually expect severe attack by the weevil in southern Louisiana and the Delta of Mississippi.

## INSECTS OFTEN MISTAKEN FOR THE BOLL WEEVIL.

The anticipated appearance of a serious pest such as the boll weevil in new regions causes greater attention to be given to the insects found in the cotton fields. Many planters notice common native insects which appear to answer the description of the boll weevil. The result of such mistaken identifications is generally a local panic. On account of the difficulty of distinguishing the boll weevil from a large number of related insects, we advise that whenever a planter discovers an insect which he suspects to be the boll weevil he send it either to the State entomologist or to the Bureau of Entomology and receive authoritative information.[1]

[1] Addresses of officials who will give authentic determinations of the boll weevil:
*Alabama.*—W. E. Hinds, Auburn.
*Arkansas.*—Paul Hayhurst, Fayetteville.
*Florida.*—E. W. Berger, Gainesville.
*Georgia.*—E. L. Worsham, Atlanta.
*Louisiana.*—J. B. Garrett, Baton Rouge.
*Mississippi.*—R. W. Harned, Agricultural College.
*North Carolina.*—Franklin Sherman, jr., Raleigh.
*Oklahoma.*—C. E. Sanborn, Stillwater.
*South Carolina.*—A. F. Conradi, Clemson College.
*Tennessee.*—G. M. Bentley, Knoxville.
*Texas.*—Wilmon Newell, College Station. Ernest Scholl, Austin, Department of Agriculture. W. D. Hunter, Bureau of Entomology, Dallas.
*Virginia.*—E. A. Back, Blacksburg.

Many of the weeds in the vicinity of the cotton fields are attacked by different species of weevils which may in some respects resemble the boll weevil. Some of these weevils are of a general dark color and have beaks with which to puncture their food plants. On close observation it will be found that the weevils which are discovered on other weeds are breeding in those weeds. They are not the boll weevils and will not attack the cotton. Many of these native weevils are also found on the cotton plants at the nectar which is produced by the squares, blooms, and leaves. These weevils simply visit the cotton plants in order to feed upon this nectar and do not injure the plant in any way. The following list contains the names and references to the habits of some of the most common weevils which occur in and about cotton fields:

*Insects often mistaken for the boll weevil* (*Anthonomus grandis* Boh.). (Pl. II, *a*.)

| Weevil. | Attacks. |
|---|---|
| *Anthonomus albopilosus* Dietz | Seed pods of wild sage (Croton). |
| *Anthonomus eugenii* Cano | Pepper pods. |
| *Anthonomus fulvus* Le C. (Pl. II, *b*) | Purple mallow buds. |
| *Anthonomus signatus* Say | Blackberry, dewberry, and strawberry buds. |
| *Anthribus cornutus* Say | Cotton stems. |
| *Aræcerus fasciculatus* DeG | China-berries, coffee beans, and old cotton bolls. |
| *Balaninus nasicus* Say | Acorns. |
| *Balaninus victoriensis* Chitt | Live oak acorns. |
| *Baris striata* Say | Roots of ragweed (Ambrosia). |
| *Baris transversa* Say | Roots of cockle-bur (Xanthium). |
| *Chalcodermus æneus* Boh | Cowpea pods. |
| *Conotrachelus elegans* Say (Pl. II, *f*) | Galls and nuts of pecans. |
| *Conotrachelus erinaceus* (Pl. II, *e*) | Habits unknown. |
| *Conotrachelus leucophæatus* Fab | Stems of careless weed (Euphorbia). |
| *Conotrachelus naso* LeC | Acorns. |
| *Conotrachelus nenuphar* Hbst | Fruit of plums and peaches. |
| *Desmoris constrictus* Say | Seed of sunflower (Helianthus). |
| *Desmoris scapalis* LeC | Flower heads of broad-leaved gum plant (Sideranthus). |
| *Dorytomus mucidus* Le C. (Pl. II, *d*) | Cottonwood catkins. |
| *Epicærus imbricatus* Say | Habits unknown, adult feeds on foliage. |
| *Geræus penicellus* Hbst | Habits unknown, visits cotton nectar. |
| *Geræus picumnus* Hbst | Habits unknown, visits cotton nectar. |
| *Gerstæckeria nobilis* LeC | Joints of prickly pear. |
| *Hylobius pales* Hbst | Pine bark. |
| *Lixus scrobicollis* Boh | Stems of ragweed (Ambrosia). |
| *Pachylobius picivorus* Germ | Pine branches and bark. |
| *Pissodes nemorensis* Germ. (Pl. II, *c*) | Pine branches and bark. |
| *Rhynchites mexicanus* Gyll | Rosebuds. |
| *Rhyssematus palmacollis* Say | Morning-glory pods. |
| *Trichobaris mucorea* LeC | Tobacco stalks. |
| *Trichobaris texana* LeC | Spanish thistle stalks. (*Solanum rostratum*). |
| *Tychius sordidus* LeC | Pods of false indigo (Baptisia). |

Many other insects are sometimes mistaken for the boll weevil. This list includes only the species which are more or lesss closely allied to that insect and consequently more commonly confused with it.

## FOOD PLANTS OF THE BOLL WEEVIL.[1]

The careful investigations of Mr. E. A. Schwarz in Guatemala, Mexico, and Cuba have convinced him that the original food plants of the boll weevil are the tree cottons of those countries. One of these species has the seeds adhering together in a mass and is called "kidney" cotton from the shape of this mass. The other has seeds separated as in Upland cotton of the United States and is probably the *Gossypium brasiliense* of botanists. The former appears to be the more ancient form and presumably is the species upon which the weevil originally subsisted. Cotton is now rarely cultivated in Cuba, but the practically wild tree cottons are found throughout the island, and on these the boll weevil is generally to be found, although in very small numbers. There are, however, frequently found throughout the island isolated plants which are not infested. The areas of cultivation of cotton in Guatemala are extremely isolated, but the presence of tree cotton perpetuates the weevil and gives it a rather general distribution. In Mexico the principal regions of cotton growth are represented by narrow belts along the two coasts and a large area in the north-central portion known as the "Laguna." Tree cotton probably serves to continue the boll weevil's activity in many parts of Mexico where cotton is not cultivated. It is impossible to decide whether the boll weevil originated in Cuba or in Central America, as it occurs in practically the same condition in both places. It is, however, practically certain that the insect has attacked the cotton plant from antiquity. In fact, there is nothing to indicate that it ever had any other food plant.

The question of the possibility that the boll weevil may feed upon some plant other than cotton is one of importance. As an illustration we may state that as long as cotton is extensively produced in any given region there is comparatively little danger, but if a certain region should forego the planting of cotton for a period of years in order to escape boll-weevil injury and then resume its cultivation, it is apparent that all efforts would fail if the boll weevil could in the meanwhile exist on other native plants.

It is a well-known fact that insects which have few food plants usually confine their attacks to closely related plants belonging to the same botanical family or even genus. The native plants most closely allied to cotton in the regions so far infested are the various species of Hibiscus and the trailing mallows of the genus Callirrhoe. Careful tests have been made with these plants and with many unrelated plants, both as to their powers of sustaining life and the inducements offered for oviposition. Six species of Hibiscus, namely, *esculentus, vesicarius, manihot, moscheutos, militaris*, and *africanus*, have been tested to ascertain how long the weevil could live on them and whether it would oviposit in the fruit. In experiments conducted by Dr. W. E. Hinds hibernated weevils starved in an average time of about four days with leaves of either *Hibiscus esculentus* or *H. militaris*. Weevils

[1] There has recently been discovered by Prof. C. H. T. Townsend another serious cotton pest, *Anthonomus vestitus* Boheman, which we may designate as the Peruvian cotton square weevil, as it is not at present known outside of Peru and Ecuador. Prof. C. S. Banks has also discovered in the Philippine Islands a weevil feeding in cotton flowers which may be known as the Philippine cotton flower weevil. This species has been described as *Ecthetopyga gossypii* Pierce. The coffee-bean weevil, *Aræcerus fasciculatus* DeGeer, frequently breeds in old dried cotton bolls, and the cowpea pod weevil, *Chalcodermus æneus* Boheman, breeds occasionally in fresh cotton squares in fields of cotton following cowpeas. On account of the existence of these other square and boll weevils it is still necessary to retain the original name Mexican cotton boll weevil for *Anthonomus grandis* Boheman.

of the first generation which had fed upon no cotton were placed upon *Hibiscus militaris*, and these starved within an average of three or four days. The first-generation weevils which had fed for a few days on squares were placed upon leaves, buds, and seed pods of *Hibiscus vesicarius*. Though they fed a little, all starved in an average of about five days. A lot of first-generation weevils, fed first for several days with squares, were given leaves, buds, and seed pods of okra More feeding was done by this lot than by any other, all parts being slightly attacked. These weevils lived for an average of seven days. In experiments conducted independently by Messrs. Tucker and Jones at Alexandria and Shreveport, La., and Dallas, Tex., with *H. moschuetos*, *H. militaris*, and *H. africanus*, weevils were found to feed slightly on the pods, and fertile eggs were also found on the outside of the pods, but none were ever placed within.

No results whatever were obtained by experiments with a species of Abutilon. In an experiment with hollyhock (*Althæa* sp.) three weevils lived an average of six days. In experiments by Mr. W. W. Yothers with buds of *Callirrhoe involucrata*, 42 weevils were fed for an average of 5.6 days, the maximum length of life being 11 days. These records show that the weevils may possibly be able to feed for a few days on some of the other malvaceous plants and that they may even be forced to oviposit, but that under present conditions they are unable to sustain life or to reproduce in these plants. The maximum length of life which they have been able to live on any of these plants is hardly greater than they could live with sweetened water (see Table XIII).

Unsuccessful attempts were made to cause the weevil to feed upon sunflower (*Helianthus annuus*), bindweed (*Convolvulus repens*), the pigweeds (*Amaranthus hybridus* and *A. spinosus*), the ragweed (*Ambrosia psilostachya*), and various other species of weeds and grasses which occur more or less frequently around cotton fields.

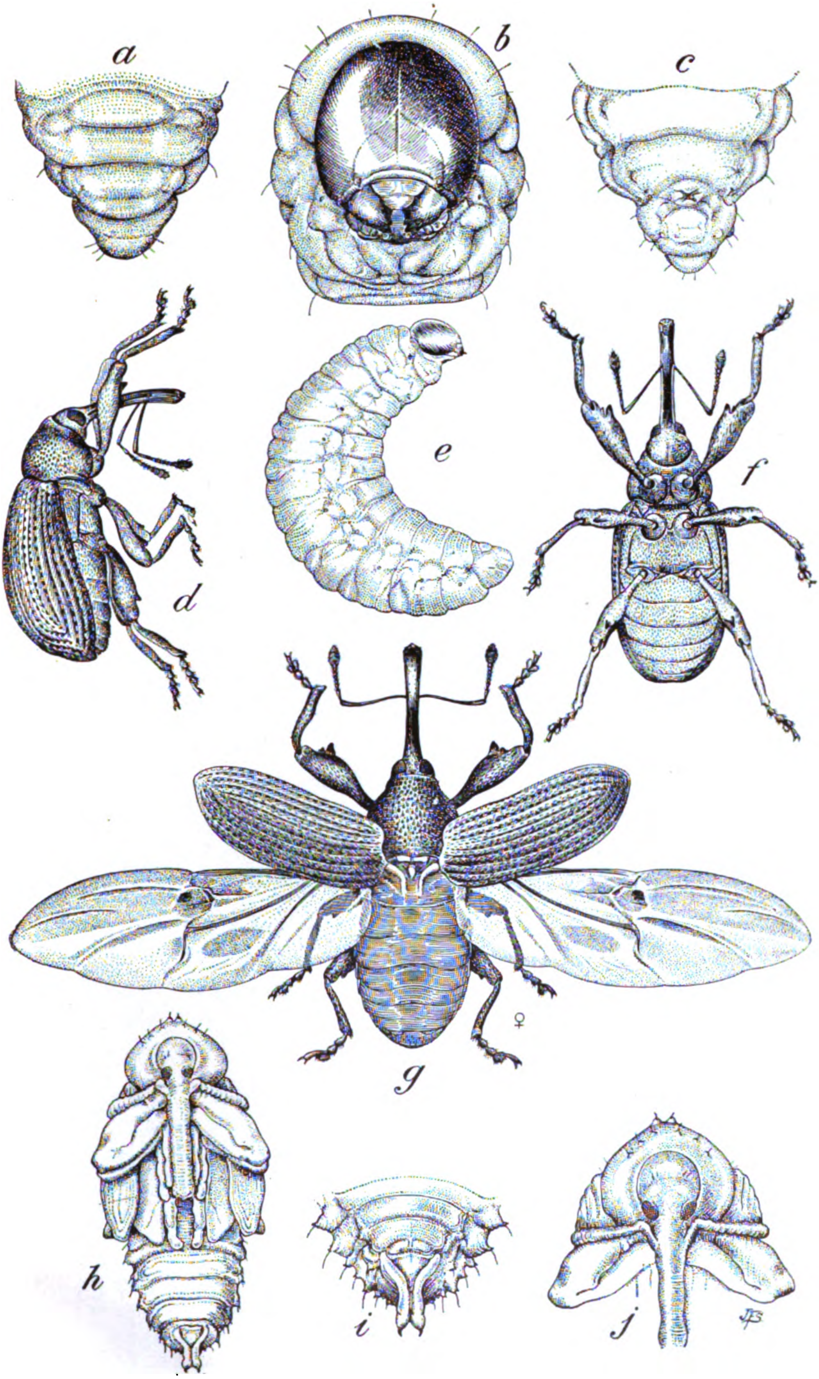
Throughout the investigations of Prof. C. H. T. Townsend in southern Texas and Mexico and of Mr. E. A. Schwarz in Texas, Cuba, Mexico, and Guatemala, and the observations made by the writers and their associates in all the infested region of the United States, every plant closely related to cotton has been most carefully watched. The uniform failure to find the weevil feeding upon any other plant makes it practically certain that cotton is its only food plant. Of course, the insect sometimes alights upon other plants, as it does upon fence posts and other objects. Such occurrences are altogether accidental. Frequent reports of the finding of the weevil breeding in other plants are due to mistaking some other insect for the enemy of cotton.

## LIFE HISTORY.

### SUMMARY.[1]

The egg is deposited by the female weevil in a cavity formed by eating into a cotton square or boll. The egg hatches in a few days and the footless grub begins to feed, making a larger place for itself as it grows. During the course of its growth the larva sheds its skin at least three times, the third molt being at the formation of the pupa, which after a few days sheds its skin, whereupon the transformation

[1] Extract from Bulletin 51, Bureau of Entomology, pp. 30, 31.




ANATOMICAL STRUCTURE OF THE BOLL WEEVIL.

*a*, Dorsal view of anal segments of larva; *b*, front view of head and anterior segments of larva; *c*, ventral view of anal segments of larva; *d*, lateral view of adult; *e*, lateral view of larva; *f*, ventral view of adult; *g*, dorsal view of adult with wings spread; *h*, ventral view of pupa; *i*, ventral view of anal segments of pupa; *j*, ventral view of anterior portion of pupa. (Original.)

becomes completed. These immature stages require on the average between two and three weeks. A further period of feeding equal to about one-third of the preceding developmental period is required to perfect sexual maturity so that reproduction may begin.

## DESCRIPTION.

### THE EGG.[1]

The egg of the boll weevil is an unfamiliar object even to many who are thoroughly familiar with the succeeding stages of the insect. If laid upon the exterior of either square or boll, it would be fairly conspicuous on account of its pearly white color. Measurements show that it is, on the average, about 0.8 mm. long by 0.5 mm. wide. Its form is regularly elliptical, but both form and size vary somewhat. Some eggs are considerably longer and more slender than the average, while others are ovoid in shape. The shape may be influenced by varying conditions of pressure in deposition and the shape of the cavity in which it is placed. The soft and delicate membrane forming the outer covering of the egg shows no noticeable markings, but is quite tough and allows a considerable change in form. Were the eggs deposited externally they would doubtless prove attractive to some egg parasite as well as to many predatory insect enemies. Furthermore, the density of the membranes would be insufficient to protect the egg from rapid drying or the effects of sudden changes in temperature. All these dangers the female weevil avoids by placing the eggs deeply within the tissue of the squares or bolls upon which she feeds. As a rule, the cavities which receive eggs are especially prepared therefor and not primarily for obtaining food. Buried among the immature anthers of a square or on the inner side of one carpel of a boll, as they frequently are, weevil eggs become very inconspicuous objects and are found only after careful search.

### THE LARVA.[2]

(Pl. III, *a*, *b*, *c*, *e*.)

The young larva, upon hatching from the egg, is a delicate, white, legless grub of about 1 mm. ($\frac{1}{25}$ inch) in length. Except for the brown head and dark brown mandibles the young larva is at first as inconspicuous as the egg from which it came. As it feeds and grows it continues to enlarge a place for itself in the square or boll until the food supply has become exhausted or the vegetable tissues are so changed as to be unsuitable for food. By this time, as a rule, the interior of the square has been almost entirely consumed and the larval castings are spread thickly over the walls of the cavity. This layer becomes firmly compacted by the frequent turning of the larva as it nears the end of this stage. In the cell thus formed occur the marked changes from the legless grub to the fully formed and perfect beetle.

Throughout this stage the body of the larva preserves a ventrally curved, crescentic form. The color is white, modified somewhat by

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[1] Extract from Bulletin 51, Bureau of Entomology, p. 31.
[2] Extract from Bulletin 51, Bureau of Entomology, pp. 34, 35.

the dark color of the body contents, which show through the thinner, almost transparent portions of the body wall. The dorsum is strongly wrinkled or corrugated, while the venter is quite smooth. The ridges on the dorsum appear to be formed largely of fatty tissue. After becoming full grown the larva ceases to feed, the alimentary canal becomes emptied, and both the color and form of the larva are slightly changed. The dark color disappears from the interior and is replaced by a creamy tint from the transforming tissues within. The ventral area becomes flattened, and the general curve of the body is less marked. Swellings may be seen on the sides of the thoracic region, and when these are very noticeable pupation will soon take place.

### THE PUPA.[1]

(Pl. III, *h*, *i*, *j*.)

When the pupal stage is first entered the insect is a very delicate object both in appearance and in reality. Its color is either pearly or creamy white. The sheaths for the adult appendages are fully formed at the beginning of the stage, and no subsequent changes are apparent except in color. The eyes first become black, then the proboscis, elytra, and femora become brownish and darker than the other parts. The pupa of the boll weevil can be distinguished readily from any other pupa which might be found in a cotton square or boll. Like all other curculionid pupæ, its beak rests on the venter of the body, with the legs drawn up at the sides and with the elytra on the dorsum as they will appear in the adult. But the boll-weevil pupa has two large quadrate tubercles on the prothorax, practically at the anterior apex of the body, and the abdominal segment which serves as the apex is produced in a rather chitinous flattened process, which is inflated at the middle and deeply quadrately emarginate at apex, leaving only two strong acute teeth projecting.

The final molt requires about 30 minutes. The skin splits open over the front of the head and slips down along the proboscis and back over the prothorax. The skin clings to the antennæ and the tip of the proboscis until after the dorsum has been uncovered and the legs kicked free. Then by violently pulling upon the skin with the forelegs the weevil frees first the tip of the snout and then the antennæ, and finally with the hind legs it kicks the shrunken and crumpled old skin off the tip of the abdomen.

### THE ADULT.

(Pl. II, *a*; Pl. III, *d*, *f*, *g*.)

#### BEFORE EMERGENCE.

Immediately after its transformation from the pupa the adult is very light in color and comparatively soft and helpless. The proboscis is darkest in color, being of a yellowish brown; the pronotum, tibiæ, and tips of the elytra come next in depth of coloring. The elytra are pale yellowish, as are also the femora. The mouth parts, claws, and

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[1] Modified and expanded from Bulletin 51, Bureau of Entomology, p. 38.

the teeth upon the inner side of the fore femora are nearly black. The body is soft, and the young adult is unable to travel, consequently this period is passed where pupation occurs. Usually two or more days are required to attain the normal coloring and the necessary degree of hardness to enable the adult to make its escape from the square or cell.[1] This is known as the teneral adult stage.

### DESCRIPTION OF ADULT.

The following technical description of the species is taken from the Revision of Genera and Species of Anthonomini Inhabiting North America, by Dietz.[2]

*Anthonomus grandis* Boh.—Stout, subovate, rufo-piceous and clothed with coarse, pale-yellowish pubescence. Beak long, slender, shining, and sparsely pubescent at the base; striate from base to the middle, striæ rather coarsely punctured; apical half finely and remotely punctured. Antennæ slender, second joint of funicle longer than the third; joints 3–7 equal in length, but becoming gradually wider. Head conical, pubescent, coarsely but remotely punctured, front foveate. Eyes moderately convex, posterior margin not free. Prothorax one-half wider than long; base feebly bisinuate, posterior angles rectangular; sides almost straight from base to middle, strongly rounded in front; apex constricted and transversely impressed behind the anterior margin; surface moderately convex, densely and subconfluently punctured; punctures irregular in size, coarser about the sides; pubescence more dense along the median line and on the sides. Elytra oblong, scarcely wider at the base than the prothorax; sides subparallel for two-thirds their length, thence gradually narrowed to and separately rounded at the apex, leaving the pygidium moderately exposed; striæ deep, punctures large and approximate; interstices convex, rugulose, pubescence somewhat condensed in spots. Legs rather stout, femora clavate, anterior strongly bidentate, inner tooth long and strong, outer one acutely triangular and connected with the former at the base; middle and posterior thighs unidentate. Tibiæ moderately stout, anterior bisinuate internally, posterior straight; tarsi moderate, claws broad, blackish, and rather widely separate; tooth almost as long as claw. Long. 5–5.5 mm.; 0.20–0.22 inch.

### SIZE OF WEEVILS.

The size of boll weevils is somewhat variable. It varies almost directly in proportion to the abundance of the larval food supply and the length of the period of larval development. It also depends upon the nature of the food, whether it is squares or bolls.[3] The smallest weevils are developed from squares which are very small, and which, for some reason, either of plant condition or of additional weevil injury, fall very soon after the egg is deposited. In such cases the supply of food is not only small, but possibly, owing to the immaturity of the pollen sacs, its quality is poor. Normally, squares continue to grow for a week or more after eggs are deposited in them, and such squares produce the weevils of average size and color.

The largest weevils are produced in bolls which grow to maturity. In them the food supply is most abundant, and the period of larval development is several times as long as it is in squares. Weevils reared from squares late in the season, where infestation has reached its maximum, are of small size, whereas weevils reared from large bolls are very noticeably larger. The extremes are so great that the largest and smallest weevils would be thought, by one not familiar

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[1] The foregoing is extracted from Bulletin 51, Bureau of Entomology, p. 39.
[2] Trans. Amer. Ent. Soc., vol. 18, p. 205.
[3] The following sentences are taken from Bulletin 51, Bureau of Entomology, p. 41.

with them, to be of entirely different species. So far as dimensions may convey an idea of the size, we may say that the weevils range from 2.5 mm. to 6.75 mm. ($\frac{1}{10}$ to $\frac{1}{4}$ inch) in length, measuring from base of beak to apex of elytra, and from 1 mm. to 3 mm. ($\frac{1}{25}$ to $\frac{1}{8}$ inch) in breadth at the middle of the body.

### WEIGHT OF WEEVILS.

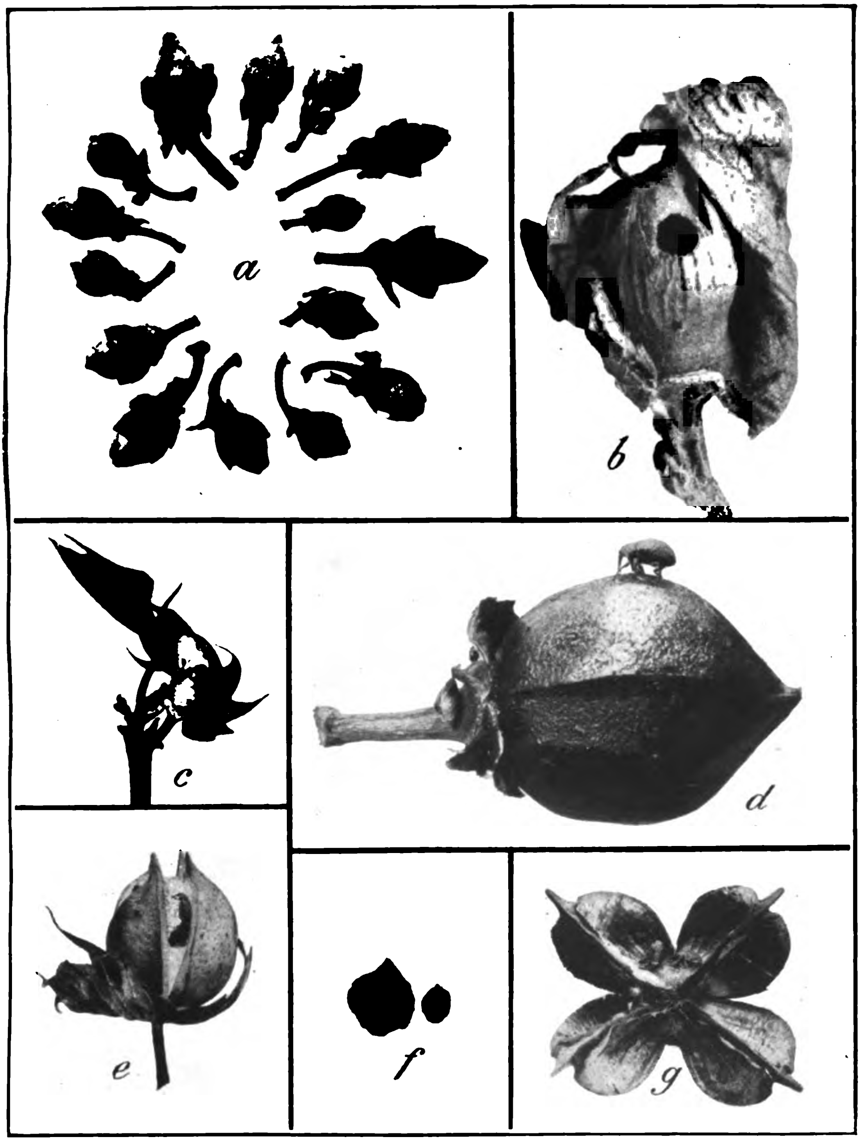
A number of interesting observations have been made at various times upon the weight of weevils in connection with the nature of the food supply. These observations have been tabulated, as follows:

TABLE VII.—*Weight of boll weevils from different sources.*

| Source. | Condition when weighed. | Number. | Average weight. |
|---|---|---|---|
| | | | *Grains.* |
| Picked small squares | Fed | 25 | 0.105 |
| Average fallen squares | do | 68 | .231 |
| Do | Unfed | 36 | .102 |
| Do | Fed | 9 | .110 |
| Fallen squares | do | 15 | .080 |
| Large bolls | do | 69 | .268 |
| Total | | 222 | |
| Average | | | .192 |

### COLOR OF WEEVIL.

Color is very often a variable character in insects, and the boll weevil presents considerable range in this respect. Normally, the general color becomes darker with age. Consequently, hibernated weevils are the darkest found, but another factor must be considered. As has been noted, whatever influences the size of the larva affects directly the size of the adult, and it is noticeable that weevils of the same size are also, as a rule, similar in color. In general, the smaller the size of the weevil, the darker brown is its color; the largest weevils are light yellowish brown. Between these two extremes are the majority of average-sized weevils, which are either of a gray-brown or dark yellow-brown color. In the opinion of Dr. W. E. Hinds the principal reason for the variation in color lies in the degree of development of the minute, hair-like scales, which are much more prominently developed in the large than in the small specimens, although the color of old specimens is often changed by the abrasion of the scales. These scales are yellow in color, while the ground color of the chitin bearing them is a dark brown or reddish brown. The development of the scales appears to take place mostly after the adult weevils have become quite dark in color, but before the chitin becomes fully hardened. They seem, therefore, to be, to a certain extent, an aftergrowth which depends upon the surplus food supply remaining after the development of the essential parts of the weevil structure.




THE ADULT BOLL WEEVIL AND EMERGENCE HOLES.

*a*, Squares of Peruvian cotton, showing emergence holes of the Peruvian cotton-square weevil; *b*, square of upland cotton, showing emergence hole of the cotton-boll weevil; *c*, adult boll weevil on cotton square; *d*, adult boll weevil puncturing cotton square; *e*, adult boll weevil emerging from cotton boll; *f*, small dry bolls, showing emergence holes; *g*, hull of boll, with weevils found hibernating. (Original.)

## SECONDARY SEXUAL CHARACTERS.[1]

We are indebted to Dr. A. D. Hopkins, of the Bureau of Entomology for indicating the most strongly marked points of difference in the secondary sexual characters of the boll weevil. (See fig. 3.) The distinctive characters are found upon the snout and upon the last two abdominal segments. The differences are subject to some variation, but are still sufficiently constant to enable a close observer with the aid of a hand lens positively to differentiate males from females.

*Female.*—The snout of the female is slightly longer and more slender than that of the male. When viewed from above it usually appears to taper slightly from each end toward the middle. The antennæ are inserted slightly farther from the tip than is the case in the male. The insertion is at about two-fifths of the distance from the tip of the snout to the eyes. As a rule the surface of the snout is more smooth and shining than in the male. A slight depression,

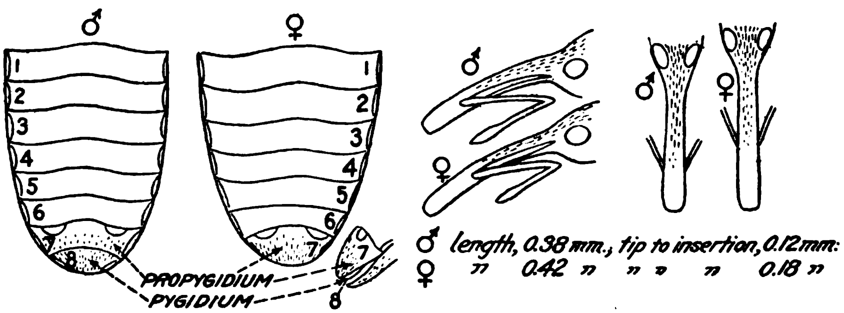



FIG. 3.—Secondary sexual characters of *Anthonomus grandis*. (From Hinds and Yothers, after Hopkins.)

rather elongated and much larger than any of the other punctures upon the snout, occurs between the bases of the antennæ. When the wing covers and wings are unfolded the abdomen shows seven distinct dorsal segments. The last segment visible in the female, called the propygidium, can be seen only from the sides.

*Male.*—In the male the snout is slightly shorter, thicker, and more coarsely punctured than in the female. The depression mentioned in the female is lacking. The antennæ are inserted at practically one-third of the distance from the tip of the snout to the eyes. The sides of the snout are very nearly parallel. In the abdomen the male shows eight distinct dorsal segments, the terminal segment (pygidium) not being covered by the propygidium as is the case in the female.

In general practice an examination of the beak is sufficient to determine the sex of each weevil.

[1] This discussion is modified from Bull. 77, Bureau of Entomology, pp. 91, 92.

## SEASONAL HISTORY.

### THE ADULT WEEVIL.

#### EMERGENCE.[1]

(Pl. IV, *b, e;* Pl. VI, *e, f.*)

The adult boll weevil's normal method of escape from squares and small bolls is by cutting with its mandibles a hole just the size of its body. In large bolls the escape of the weevil is greatly facilitated by the natural opening of the boll. Often the pupal cell is broken open by the spreading of the carpels, and when this is the case the pupa, if it has not already transformed, becomes exposed to the attack of enemies or, what is probably a more serious menace, to the danger of drying so as seriously to interfere with a successful transformation. If the cell remains unbroken the weevil always escapes by the path of least resistance, cutting its way through as in the case of a square.

#### CHANGES AFTER EMERGENCE.[2]

At the time of emergence the weevils are comparatively soft, and they do not attain their final degree of hardness for some time after they have begun to feed. The chitin is of an orange tinge at the time the weevils leave the squares or bolls, but after exposure for some time it turns to a dark chocolate brown.

#### PROTECTIVE HABITS.

Not only is the boll weevil protected from its enemies by its color, which resembles both the dry squares and also the pulverized soil upon which it frequently drops, but it has a protective habit, found more or less commonly among insects. At the first disturbance of the cotton plant, or sometimes even at a movement of a large object in the vicinity of the cotton plant, the boll weevil becomes very alert, raising its antennæ and standing almost motionless. If the disturbance continues, the weevil falls to the ground with its legs drawn up close to the body and the antennæ retracted against the beak, which is brought inward toward the legs. In this position it often remains motionless for some time, but if further disturbed, it will start up quickly, run a short distance and again fall over, feigning death. This habit is popularly known as "sulling"[3] or "playing possum." Frequently, in falling, the weevil comes in contact with some part of the plant and immediately relaxes and takes shelter on the plant, or sometimes it spreads its wings and flies away instead of falling to the ground. In July and August the weevils become more alert than at any other season of the year, and flight more frequently follows the dropping from the plants.

#### FOOD HABITS.

Before escaping from the square the adult empties its alimentary canal of the white material remaining therein after the transformation. The material removed in making an exit from the cell is not used as

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[1] Extracted from Bull. 51, Bureau of Entomology, pp. 39, 40.
[2] Extracted from Bull. 51, Bureau of Entomology, p. 40.
[3] Undoubtedly a corruption of "sulking."

food, but is cast aside. Weevils are ready to begin feeding very soon after they escape from the squares or bolls in which the previous stages have been passed. For several days thereafter both sexes feed almost continuously. They much prefer squares, but in confinement will feed upon leaves, flowers, or bolls. Under natural conditions any portions of the plants other than the squares and bolls are seldom attacked. The bolls are only slightly attacked so long as there is an abundance of uninfested squares.

[1] The method of feeding is alike in both sexes. The mouth parts are very flexibly attached at the tip of the snout (fig. 4) and are capable of a wide range of movement. The head fits smoothly into the prothorax like the ball into a socket joint and is capable of a considerable angle of rotation. The proboscis itself is used as a lever in prying, and helps to enlarge the puncture through the floral envelopes especially. Feeding is accomplished by a combination of movements. The sharply toothed mandibles serve to cut and tear, while the rotation of the head gives the cutting parts an auger-like action. The forelegs especially take a very firm hold upon the square and help to bring a strong pressure to bear upon the proboscis during certain portions of the excavating process. The outer layer of the square, the calyx of the flower, is naturally the toughest portion that the weevil has to penetrate, and only enough is here removed to admit the snout. After that is pierced the puncture proceeds quite rapidly, combinations of chiseling, boring, and prying movements being used. While the material removed from the cavity is used for food, the bulk of the feeding is upon the tender, closely compacted, and highly nutritious anthers or pollen sacs of the square. When these are reached the cavity is enlarged, and as much is eaten as the weevil can reach. The form of the entire puncture becomes finally like that of a miniature flask.

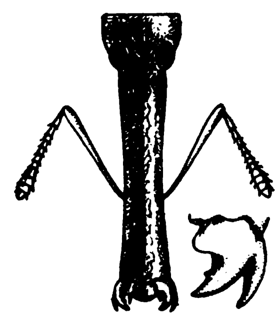

FIG. 4.—Cotton-boll weevil: Head, much enlarged, showing rostrum, with antennæ near middle and mandibles at end; mandible, more enlarged, at right. (Original.)

Only after weevils have fed considerably do sexual differences in feeding habits begin to appear; from this time on the females puncture mainly the base and the males the tip of the square.

Feeding punctures are much larger and deeper than are those made especially for the reception of the eggs; more material is removed from the inside of the square or boll and the opening to the cavity is never intentionally closed. Feeding punctures are most frequently made through the thinner portion of the corolla not covered by the calyx. The exposed tissue around the cavity quickly dries and turns brown from the starting of decay. As a number of these large cavities are often formed in one square (Pl. V, *c*), the injury becomes so great as to cause the square to flare immediately, often before the weevil has ceased to feed upon it. Squares so severely injured fall in a very short time. The injury caused by a single feeding puncture is often overcome by the square, which continues its normal course of development. When feeding punctures are made in squares which are nearly ready to bloom, the injury commonly produces a distorted

[1] The following four paragraphs are borrowed from Bulletin 51, Bureau of Entomology, pp. 50, 51.

bloom (Pl. V, *e*, *f*), and in very severe cases the boll will drop soon after setting.

After the females begin to oviposit their feeding habits become quite different from those of the males. Up to this time both sexes move but little, making a number of punctures in a single square; but from this point we must consider the feeding habits of the sexes separately.

Males puncture the tip portion of the square not covered by the calyx more often than do the females. The yellow or orange colored excrement is abundant, and owing to the somewhat sedentary habits of the males it accumulates often in rather large masses, so that it is often possible to tell whether a square in the field has been attacked by a male rather than by a female weevil. Observations made by Dr. Hinds on 70 specimens under both field and laboratory conditions show that for the first few days of their life the males make from six to nine punctures a day, but that during their entire life they average about 1.2 punctures per day and an average of 2.6 punctures per square, injuring only about two squares every three days. Whether in or out of doors, the activity of feeding decreases as the male becomes older.

After they begin to oviposit females seem generally to feed less upon one square or in one puncture than they do previous to that time. They obtain quite a considerable portion of their food from the excavations which they make for the deposition of their eggs, and as they show a strong inclination to oviposit only in clean or previously uninfested squares their wandering in search of such squares keeps their punctures scattered so long as plenty of clean squares can be found. When clean squares become scarce, the normal inclination can not be followed, and the number of punctures made in each square will be greatly increased.

Table VIII is presented to illustrate the feeding activity of both sexes:

TABLE VIII.—*Rate of making egg and feeding punctures by the boll weevil.*[1]

| Character of lot. | Number of males. | Number of females. | Total. | | | Average. | | |
|---|---|---|---|---|---|---|---|---|
| | | | Weevil days. | Feeding punctures. | Egg punctures. | Feeding punctures per weevil day. | Egg punctures per female day. | Period of observation. |
| | | | | | | | | *Days.* |
| Hibernated weevils in laboratory | 55 | 54 | 4,938 | 17,406 | 5,702 | +3.5 | +2.3 | +45.3 |
| Weevils of first generation in laboratory | 31 | 27 | 3,258 | 16,487 | 3,565 | +5.0 | −2.4 | −56.2 |
| Hibernated females in field cage | ........ | 4 | 93 | 284 | 489 | +3.0 | −5.3 | −23.3 |
| First-generation females in field cage | ........ | 5 | 70 | 263 | 435 | −3.8 | +6.2 | 14.0 |
| Males in laboratory | 65 | ........ | 2,492 | 5,617 | ........ | −2.3 | ........ | +38.3 |
| Males in field | 5 | ........ | 145 | 177 | ........ | 1.2 | ........ | +29.0 |
| Total | 156 | 90 | 10.996 | 40,234 | 10,191 | ........ | ........ | ........ |
| Average | ........ | ........ | ........ | ........ | ........ | 3.6 | 2.4 | 44.7 |

[1] Modified from Bulletin 51, Bureau of Entomology, p. 52.


EFFECTS OF BOLL-WEEVIL ATTACK ON LEAF AND SQUARES.

*a*, Cotton leaf much fed upon by adults; *b*, square with two egg punctures; *c*, flared square with many feeding punctures; *d*, square prevented from blooming by puncture; *e*, bloom injured by feeding punctures; *f*, poor blooms caused by feeding punctures. (Original.)

### ABILITY TO LOCATE COTTON.

When hibernated weevils emerge from their winter quarters in search of food they are frequently long distances from the nearest cotton field. It has been a question of considerable interest whether the weevils are able to locate cotton or whether they find it by chance. Dr. A. W. Morrill conducted a series of experiments in the laboratory to test the attraction of cotton squares for the weevil, but the results were not conclusive. In the eight years of study of the boll weevil, there have been very few records of weevils on any other plants than cotton, notwithstanding the fact that special collections were made in the woods and fields near the cotton fields in search of boll weevils. In the season of 1905 extensive collections were made by means of sweeping nets by several men for weeks during the dispersion season, and yet not a single weevil was found outside of the cotton fields. All of this would indicate that there is some attraction of the weevils to cotton. The concentration of weevils upon the earliest plants in the spring and upon the greenest and most luxuriant portions of the fields in the fall are also evidences of the ability of the weevils to find desirable places for feeding.

### FEEDING HABITS OF HIBERNATED WEEVILS.

Whether there be few or many hibernated weevils makes no difference in their feeding habits. The stage of the cotton at the date of emergence determines largely the nature of the food habits at that time. The first weevils to emerge obtain their food from the tender, rapidly growing, terminal portions of the young plants. They place themselves upon the node where the two cotyledons branch. In fact, this seems to be the point usually attacked in cases of very young cotton plants. In almost all cases the puncture of the weevil at this point results in the death of the plant. Sometimes the attack is made a little above the node on a petiole of the cotyledon, in which case the one cotyledon falls and the other remains, and the plant usually recovers. However, it frequently happens that the same weevil attacks both of the cotyledons. This form of attack is fatal to the seedlings unless they have become very vigorous—sometimes until they have developed two true leaves. Later the central bud, young leaves, or tender stems are attacked, and upon these the weevils easily subsist until the squares are developed. (See Pl. V, *a*.) In cases where the emergence from hibernation is very large the weevils may come out in such numbers upon the newly sprouted cotton as to stunt or even kill the growing plants by their depredations upon the terminal portion.

Weevils which have fed upon tender tips of plants seem perfectly satisfied with their food supply, and it appears that their first meal upon squares is largely the result of accident. After having begun to feed upon squares, however, it appears that their taste becomes so fixed that they normally seek for squares.

In the spring of 1895 Mr. E. A. Schwarz found the first emerged hibernated weevils working upon plants which had sprung from 2-year-old roots. In the spring of 1903 in one field of comparatively early cotton, 2 or 3 acres in extent, the senior author found, between April 24 and May 11, 23 weevils working on the buds and tender leaves of stubble plants before a single weevil was found on the

young planted cotton having from four to eight leaves. At Victoria, early in June, 1902, Mr. A. N. Caudell found, in examining 100 stubble plants growing in a planted field, that fully one-half of the squares upon these plants were then infested. The planted cotton was just beginning to form squares and was slightly injured at that time.

It appears, therefore, that stubble plants, where such exist, receive a large part of the first attack of the hibernated weevils, not because of any special attraction, but for the reason that they are present long before the planted cotton has come up. The occurrence of volunteer and stubble cotton in the fields in the early spring is of considerable importance in the boll-weevil problem. Throughout the coast regions, especially of southern Texas, stubble cotton is very common in the fields, and there is hardly a region of the South where volunteer cotton can not be found before the normal planting is up. (See Pl. VIII, *a*.)

It is by no means certain that all or even a large proportion of the hibernated weevils may be found upon the early plants, and this renders their use as traps entirely impracticable. A number of observations have shown that weevils frequently occur upon the planted cotton, even when numbers of vigorous stubble plants may be found within a comparatively short distance. In fact, at Victoria, Tex., in 1904, many weevils were found feeding upon the planted cotton for more than six weeks after the stubble plants were producing fruit.

### DESTRUCTIVE POWER BY FEEDING.[1]

A glance at the figures in Table VIII is sufficient to show the great destructive power of the Mexican cotton-boll weevil. It may be seen that both in the field and in the laboratory the weevils of the first generation are more active in making punctures than are the hibernated weevils. These generations overlap too far to justify us in attributing this difference to the influence of a higher temperature alone, though this factor will account for a large part of it. A comparison of the figures for males alone with those for females alone or with those for males and females together shows that it is very conservative to state that males make less than half as many punctures as do females. By the habit of distributing their punctures among a greater number of squares the destructiveness of the females becomes at least five times as great as that of the males.

This great capacity for destruction has been one of the most evident points in the history of the spread of the weevil and has deeply impressed the entomologists who first studied the insect in Texas. In 1895 Mr. E. A. Schwarz, in writing of the work of the weevil at Beeville, said:

> Each individual specimen possesses an enormous destructive power and is able to destroy hundreds of squares, most of them by simply sticking its beak into them for feeding purposes.

### ATTRACTIVENESS OF VARIOUS SUBSTANCES.

Experiments have proved that the report which has sometimes been circulated to the effect that cottonseed meal attracts the weevil is due to mistaking other insects for it. Many tests, both in the laboratory

[1] Extracted from Bulletin 51, Bureau of Entomology, p. 61.

and in the field, have shown that sugar and molasses, either in solution or otherwise, have no attraction whatever for the weevil. Honey exerts a very weak attraction, but not enough to be of any practical use in control. In fact, it has not been found that any substance exerts a special attraction for the weevil. The experiments have dealt with many chemicals as well as plant decoctions.

### SENSE OF COLOR.

A series of interesting observations on the color sense of the boll weevil was made by Mr. C. R. Jones at Calvert and Victoria, Tex., and Alexandria, La., in 1907. Tubes of different colors were placed in a box, all with an equal amount of sunlight, and the weevils were given food. The observations were made at intervals during the day, and each time the weevils were all shaken back into the box. Table IX shows the total number of weevils found at each color for the series of observations and also the weighted average attractiveness. Fourteen shades were used, but these may be grouped under eight colors. The three most attractive shades were light-blue, dark-green, and light-pink. While it is rather difficult to explain the results, it nevertheless appears that there is some preference for certain colors on the part of the weevil.

TABLE IX.—*Relative attractiveness of colors to the boll weevil.*

| Color. | Number of observations. | Number of weevils attracted. | Average attractiveness. |
|---|---|---|---|
| | | | *Per cent.* |
| Blue | 64 | 461 | 7.2 |
| Green | 43 | 261 | 6.0 |
| Yellow | 32 | 123 | 3.8 |
| Red | 107 | 411 | 3.8 |
| White | 11 | 24 | 2.1 |
| Purple | 32 | 29 | .8 |
| Orange | 10 | 5 | .5 |
| Black | 21 | 6 | .2 |

### MOVEMENTS ON FOOD PLANT.

Various observations have been made to determine the amount of movement of weevils at night. In July, 1904, at a mean temperature of 76.3° F., Mr. A. C. Morgan found, in an aggregate of 134 weevil nights, that eight weevils had moved but 25 times. Each weevil had moved only once every six nights. On cloudy days weevils are much more sluggish than on sunny days. Relative humidity influences the activity, but no definite observations on this point have been made.

The effect of temperature on locomotive activity may well be illustrated by a series of laboratory experiments conducted by Dr. A. W. Morrill. A thermometer was passed through a cork and inclosed in a test tube, which in turn was placed within a hydrometer cylinder of sufficient depth to inclose it. Weevils were inclosed in the test tube with the thermometer, and the temperature of the cylinder was varied either by heating gently or by the use of ice water. Starting with the thermometer at 64° F., the 10 weevils inclosed were found to move slowly, half of them being quiet. As the temperature was gradually

raised the activity of the weevils increased up to 105° F. When the temperature reached 95° F. or over the weevils were running up and down the tube. By filling the cylinder with cold water the temperature was lowered to 86° F., at which point the weevils began to cluster at the top on the cork and were crawling slowly. By the addition of ice in the cylinder the temperature was lowered to 59° F., at which point five weevils were struggling on the bottom of the test tube or clinging to one another, four were clustered on the stopper, while one was slowly crawling downward. At 50° F. six weevils at the bottom showed slight signs of life, and one was crawling slowly. At 45.5° F. slight signs of life were still shown, while at 40° F. occasional movements only were noted. When the temperature was raised weevils began crawling as 50° F. was passed, and at 64° all had left the bottom and were crawling upward. Some recovered more quickly than did others. The temperature was again lowered, this time by the use of salt with ice. All movement ceased at 37° F. The cooling, however, was continued to 33° F., after which it was slowly raised to 42° F., at which point movements began.

### EFFECTS UPON SQUARES AND BOLLS OF FEEDING BY THE BOLL WEEVIL.

From numerous large, open feeding punctures a square becomes so severely injured that it flares very quickly, often within 24 hours. (See Pl. V, *c*.) Males usually make the largest punctures, which they always leave open while they remain for a day or more working upon the same square. It has been often found that squares thus injured by a male will flare before the weevil leaves it. The time of flaring depends upon the degree of injury and the size of the square. Thus small squares which receive only a single large feeding puncture in the evening are found widely flared in the morning. On the other hand, large squares which are within a few days of the time of their blooming may receive a number of punctures without showing any noticeable flaring. Frequently a square which has flared widely will be found later to have closed again and to have formed a distorted bloom, and occasionally such squares develop into normal bolls. (See Pl. V, *e*, *f*.) In squares of medium size a single feeding puncture does not usually destroy the square. The destruction of a square by feeding results either from drying or decay which follows the weevil injury.

TABLE X.—*Destruction of squares by the feeding of the boll weevil.*

| Period. | Total number of squares punctured. | Number of squares with feeding punctures. | Total number of feeding punctures. | Average number of feeding punctures per square. | Average number of days before falling. |
|---|---|---|---|---|---|
| June–July | 751 | 170 | 335 | 1.9 | 5.8 |
| August–September | 426 | 183 | 383 | 2.0 | 4.4 |
| October–November | 176 | 74 | 216 | 2.9 | 15.2 |
| Total | 1,353 | 427 | 934 | | |
| Weighted averages | | | | 2.0 | 7.0 |


INJURY BY BOLL WEEVIL TO SQUARES.

*a*, Bloom checked by attacks of larva; *b*, square opened, showing grown larva; *c*, square opened, showing pupa; *d*, dwarfed boll opened, showing one larva and two pupæ; *e*, weevil escaping from square; *f*, emergence hole of adult in square. (Original.)


INJURY BY BOLL WEEVIL TO BOLLS.

*a*, Three larvæ in boll; *b*, emergence hole in dry unopened boll; *c*, two larvæ in boll; *d*, weevils puncturing boll, *e*, opened boll, with two locks injured by weevil; *f*, large bolls severely punctured. (Original.)

Table X shows that the number of feeding punctures per square is determined by seasonal influences, as is also the average number of days before falling. A comparison of the average time from the date of the attack to the falling of the square shows that squares which are only fed on, fall, as a rule, somewhat more quickly than do squares which only contain larvæ and have never been fed upon. Flaring takes place more rapidly as the result of feeding injury by the adult than from oviposition and injury from the developing stage. While only one egg is generally laid in a square, it appears from Table X that two feeding punctures are usually made in a square.

Bolls are quite largely fed upon after infestation has reached its height. Small and tender bolls are often thoroughly riddled by the numerous punctures and fall within a short time. (See Pl. VII.) Larger bolls may receive many more punctures but do not fall. In bolls an abnormal woody growth sometimes takes the place of the punctured fiber, and a softening and decay of the seeds often accompanies this change. One or more locks may be destroyed, while the remainder of the boll develops in perfect condition.

### SUSCEPTIBILITY OF VARIOUS COTTONS.[1]

During 1903 and 1904 experiments were conducted at Victoria, Tex., to ascertain the relative susceptibility of several varieties of American Upland, Sea Island, Egyptian, and Cuban cottons. The observations at the laboratory were made by carefully examining the plants, looking into each square, and removing every weevil and infested square found. If there were any distasteful or resistant cotton among these it would surely be found in this way, and if any variety were especially attractive to the weevils it would be equally apparent. Since infested squares were removed, the accident of association or proximity would not determine the location of the weevils found, but all might be considered as having come to the cotton with equal opportunities to make their choice of food, and accordingly their location has been considered as indicating such choice. The period of observation extended from June to November, except with the Cuban cotton, which was planted late and began to square during the latter part of August. For the purpose of this comparison both the several varieties and the various plats of the American cotton will be considered together, as no evidence of preference was found among them.

In making a comparison of the results three elements must be considered for each variety of cotton: First, the number of plants of each variety; second, the number of days during which each kind was under observation; third, the total number of weevils found on each class of cotton. The elements of numbers of plants and time under observation may be expressed by the product of those two factors forming a term which we may call "plant days." The total number of weevils found upon any class of cotton divided by the number of plant days will give the average number of weevils attracted by each plant for each day, and these numbers furnish a means of direct comparison and show at a glance the average relative attractiveness of

[1] The following discussion is extracted, but modified, from Bul. 51, Bureau of Entomology, pp. 61–64.

each class of cotton. The results of this series of experiments are tabulated below:

TABLE XI.—*Relative attractiveness of various cottons to the boll weevil.*

| Class of cotton. | Number of plants. | Total. | | | Average. | | Relative attractiveness. |
|---|---|---|---|---|---|---|---|
| | | Plant days. | Weevils found. | Infested squares. | Weevils per plant per day. | Infested squares per weevil. | |
| 1903. | | | | | | | |
| American | 62 | 4,920 | 287 | 3,507 | 0.058+ | 12.2+ | 1.0 |
| Cuban | 5 | 120 | 11 | 136 | .092− | 12.4− | 1.6+ |
| Sea island | 8 | 552 | 64 | 1,089 | .116− | 17.0+ | 2.0 |
| Egyptian | 8 | 808 | 207 | 2,013 | .256+ | 9.7+ | 4.4+ |
| Total of 3 non-American cottons | 21 | 1,480 | 282 | 3,238 | .191− | 11.5− | 3.3− |
| 1904. | | | | | | | |
| American | 60 | 3,780 | 346 | ........ | .0914 | ........ | 1.0 |
| Sea island | 5 | 315 | 117 | ........ | .371+ | ........ | 4.0 |
| Egyptian | 4 | 252 | 102 | ........ | .405− | ........ | 4.4+ |

An examination of Table XI shows that American Upland cotton is less subject to attack by the weevil than any of the others, and that Egyptian (*Mit Afifi*) is by far the most susceptible. The weevils gathered so thickly on the Egyptian cotton that the plants could not produce sufficient squares to keep ahead of the injury, and therefore the average number of squares for each weevil is only three-fourths as great with that variety as with the less-infested kinds, but the average injury to each square was greater than with any other. It is possible that the greater amount of nectar secreted by the Egyptian cotton plants is responsible for this increased attraction of the weevils.

The results are still further sustained by observations upon larger areas of American and Egyptian cotton under field conditions in three localities in Texas, no weevils being removed from either kind. At Victoria, Tex., on August 26, 1903, an examination showed that 96 per cent of Egyptian squares were infested, while an average of 13 fields of American showed 75.5 per cent. At Calvert, Tex., on September 4, Egyptian showed 100 per cent infested, while the American varieties growing alongside showed 91 per cent. Similar results were found at San Antonio. Though growing in close proximity, the Egyptian produced no staple whatever, while the American gave better than an average yield in spite of the depredations of the weevil.

At Victoria, in the experimental tract during 1904, three varieties of Egyptian cotton (Mit Afifi, Janovitch, and Ashmouni) were tested side by side with American varieties. The Egyptian varieties uniformly failed to make a pound of cotton, while the American varieties averaged 400 pounds per acre.

In accordance with these observations, it appears that in developing a variety of cotton which shall be less susceptible to weevil attack, by far the most promising field for work lies among the American varieties, and of these the very early maturing kinds are most promising.

The question of choice of different varieties for food was tested in the laboratory by Dr. A. W. Morrill, by placing squares of two kinds of cotton, American and Egyptian, in alternate rows in a rearing cage

so lettered and numbered that each square could be exactly located. Weevils were then placed so that they could take their choice of these squares, and observations from 8 a. m. to 6 p. m. were made upon the location and activity of the weevils. Though this experiment was repeated four times no positive evidence was obtained to show that weevils had any choice as to which kind of squares they fed upon. Table XII presents a summary of these results.

TABLE XII.—*Rearing-cage observations upon boll weevil choice of American and Egyptian squares.*

| Experiment. | Period of observation. | Number of observations. | Weevils used. | American squares. | | | | Egyptian squares. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Total number. | Attacked. | Feeding punctures. | Egg punctures. | Total number. | Attacked. | Feeding punctures. | Egg punctures. |
| 1 | 12 m. to 8 a. m. | 8 | 10 | 16 | 12 | 15 | 5 | 16 | 5 | 12 | 3 |
| 2 | 11.45 a. m. to 9.45 a. m. | 5 | 10 | 16 | 5 | 19 | 1 | 16 | 5 | 13 | 3 |
| 3 | 12 m. to 5 p. m. day after | 5 | 10 | 16 | 7 | 25 | 2 | 16 | 9 | 27 | 2 |
| 4 | 11.45 a. m. to 9 a. m. | 5 | 10 | 16 | 6 | 17 | 6 | 16 | 8 | 14 | 3 |
| 5 | 6 p. m. to 8 a. m. | 1 | 18 | 4 | 2 | 7 | 0 | 4 | 2 | 10 | 0 |
| | Total | 24 | 58 | 68 | 32 | 83 | 14 | 68 | 29 | 76 | 11 |

In experiments 1 and 2 the American squares were attacked more extensively than were the Egyptian, while in experiments 3 and 5 greater injury was done to the Egyptian. In experiment 4 the smaller number of egg and feeding punctures made in the Egyptian squares is counterbalanced by the larger number of squares attacked. Although the totals from these five tests show slightly less injury to the Egyptian than to the American squares, it could hardly be expected that two arbitrarily chosen series, even if of the same variety, would show any closer agreement in the points of comparison made in this table than is therein shown by the American and Egyptian squares.

Field examinations made in Cuba and Mexico on the native varieties of cotton showed them to be as susceptible to serious weevil injury as are the cultivated cottons. In some localities in Central America the dwarf character of the cotton grown, the very open method of cultivation, and certain protective adaptations on the part of the plants result in the production of fair crops, though the varieties of cotton grown are by no means immune to weevil attack.

### DURATION OF LIFE OF ADULT WEEVILS.

The subject of longevity is one which naturally divides itself into several headings. Many factors must be considered, among which are the nature of the food supply, seasonal conditions, the sex of the individual, and the time of entrance into and emergence from hibernation.

The maximum record of longevity of any boll weevil is that of a hibernated weevil at Tallulah, La. (1910), which was fed squares after emergence and lived a total of over 335 days. The maximum recorded period of hibernation without food is 240 days, and the maximum recorded length of life of hibernated weevils provided with food

after emergence is 130 days for males at Dallas, Tex. (1907), and 118 days for females at Calvert, Tex. (1907). The maximum recorded length of life of hibernated weevils unfed after emergence is 90 days for males and 88 days for females, both records being made at Dallas in 1907.

A considerable number of records are available to illustrate the relative sustaining power of the various kinds of weevil food. (See Table XIII.) These records are especially valuable in making comparisons with the sustaining power of other plants suspected of being possible food plants. It will be noticed that the same food has varying sustaining power at different seasons.

TABLE XIII.

DURATION OF LIFE OF REARED BOLL WEEVILS WITHOUT NORMAL FOOD.

| Season. | Sustenance provided. | Number of weevils. | Number of weevil days. | Average longevity. | Maximum longevity. |
|---|---|---|---|---|---|
| June-July | Hay | 18 | 47.7 | 2.5 | 7 |
| Do | Oats | 15 | 44.9 | 2.9 | 7 |
| Do | Corn | 10 | 34 | 3.4 | 5 |
| Total for reared weevils with grain. | | 43 | 126.6 | 2.9 | 7 |
| July | Tie vine | 5 | 15 | 3 | 3 |
| May | Hibiscus leaf | 2 | 6 | 3 | 3 |
| July | Sunflower | 5 | 16 | 3.2 | 4 |
| May | Okra leaf | 3 | 10 | 3.3 | 4 |
| July | Pigweed | 5 | 17 | 3.4 | 4 |
| Do | Bloodweed | 5 | 18 | 3.6 | 5 |
| Do | Bermuda grass | 5 | 19 | 3.8 | 5 |
| Total for reared weevils on weed leaves. | | 30 | 101 | 3.3 | 5 |
| June-July | Water | 79 | 339.8 | 4.3 | 9 |
| August-October | do | 72 | 306.3 | 4.2 | 11 |
| Total for reared weevils on water only. | | 151 | 646.5 | 4.28 | 11 |
| June | Jap. Hibiscus buds | 12 | 25 | 2.0 | 3 |
| August | do | 9 | 19 | 2.1 | 4 |
| July | Callirrhoe buds | 42 | 235 | 5.6 | 11 |
| June | *Hibiscus africanus* buds | 16 | 92 | 5.7 | 14 |
| July | Hollyhock buds | 3 | 18 | 6.0 | + 7 |
| Do | *Hibiscus moscheutos* buds | 6 | 36 | 6.0 | 8 |
| June | Okra buds | 10 | 78 | 7.8 | 10 |
| September | *Hibiscus militaris* buds | 42 | 305 | 7.2 | 10 |
| September-November | do | 18 | 486 | 27.0 | [1]+43 |
| Total for reared weevils on malvaceous buds. | | 158 | 1,294 | 8.1 | 43 |
| September | Fresh sorghum cane | 17 | 193 | 11.3 | 20 |
| October-November—hibernation quarters offered. | | 26 | 626 | 24.0 | 45 |

DURATION OF LIFE (AFTER EMERGENCE) OF HIBERNATED WEEVILS WITHOUT NORMAL FOOD.

| | | | | | |
|---|---|---|---|---|---|
| June-July | Excelsior | 13 | 32.5 | 2.5 | 4 |
| Do | Rice | 14 | 45.2 | 3.2 | 4 |
| Total for hibernated weevils without water. | | 27 | 77.7 | 2.8 | 4 |
| March-May | Water | 5,701 | 59,021.8 | 10.3 | 90 |

[1] This weevil then entered hibernation and remained therein 126 days.

On sweetened water 12 weevils lived an average of a little less than 6 days. Six weevils fed upon molasses alone lived an average of 11.5 days.

Without food or water 50 weevils, just developed but not fed, lived an average of 5 days; 15 which were 7 weeks old lived 6 days; and 18 which were one month old lived 7.5 days.

TABLE XIV.—*Duration of life of boll weevils with normal food.*

| Season. | Sustenance provided. | Number of weevils. | Number of weevil days. | Average longevity. | Maximum longevity. |
|---|---|---|---|---|---|
| July-September | Bolls | 37 | 684.5 | 18.5 | +20 |
| September-November | .....do | 45 | 981.0 | 21.8 | 60 |
| Total for weevils fed on bolls | | 82 | 1,665.5 | 20.3 | 60 |
| February-July | Foliage | 4,261 | 103,931.1 | 24.3 | 130 |
| October-December | .....do | 92 | 2,950.9 | 32.0 | ........ |
| Total for weevils fed on foliage | | 4,353 | 106,882.0 | 24.5 | 130 |
| April-June | Squares | 170 | 12,439.4 | 73.1 | 105 |
| June-July | .....do | 91 | 3,363.2 | 36.9 | 58 |
| August-September | .....do | 64 | 4,796.0 | 74.9 | 135 |
| September-October | .....do | 18 | 1,170.0 | 65.0 | +76 |
| October-December | .....do | 10 | 359.0 | 35.9 | ........ |
| Total for weevils fed on squares | | 353 | 22,127.6 | 62.7 | 135 |

These records show the following longevity for weevils fed on different portions of the cotton plant: On bolls, 20.3 days; on foliage, 24.5 days; on squares, 62.7 days. The sustaining power of foliage is therefore about 20 per cent higher than that of bolls, and that of squares 150 per cent higher than that of foliage. This indicates that the squares are by far the most suitable form of food.

A number of observations were made on the relative longevity of weevils of different generations when fed upon cotton squares. Weevils of the first generation lived 57 days; of the third, 48.5 days, and of the fifth, 65 days.

Newly reared weevils evidently have not the vitality of weevils emerged from a long hibernation, for they can not live so long on water alone. The boll weevil can find nourishment in several species of malvaceous plants which will sustain life twice as long as water alone, and in certain conditions as long as cotton foliage. It is interesting to note that the sweetened water from sorghum cane had almost three times the sustaining power of pure water.

In connection with these studies figures were obtained upon the relative food value of the various foods to the two sexes. The data obtained may be tabulated as follows.

TABLE XV.—*Duration of life of boll weevils according to sex.*

| Condition. | Season. | Food provided. | Males. | | | Females. | | |
|---|---|---|---|---|---|---|---|---|
| | | | Number. | Weevil days. | Longevity. | Number. | Weevil days. | Longevity. |
| Hibernated | June | None | 7 | 13.3 | 1.9 | 6 | 19.2 | 3.2 |
| Reared | June-July | Hay | 9 | 19.8 | 2.2 | 9 | 27.9 | 3.1 |
| Do | do | Oats | 7 | 18.9 | 2.7 | 8 | 26.0 | 3.25 |
| Do | do | Corn | 5 | 17.0 | 3.4 | 5 | 17.4 | 3.4 |
| Hibernated | June | Rice | 8 | 27.2 | 3.4 | 6 | 18.0 | 3.0 |
| Reared | do | Water | 4 | 14.8 | 3.7 | 8 | 30.8 | 3.85 |
| Hibernated | March-June | do | 2,638 | 27,052.5 | 10.2 | 1,980 | 19,895.5 | 10.0 |
| Reared | July-September | Bolls | 16 | 315.2 | 19.7 | 21 | 319.2 | 15.2 |
| Hibernated | March-July | Foliage | 1,672 | 42,185.7 | 24.6 | 1,337 | 34,752.1 | 25.9 |
| Do | do | Squares | 90 | 7,207.0 | 80.0 | 68 | 4,752.0 | 69.8 |
| Reared | July-October | do | 57 | 3,198.0 | 56.1 | 44 | 2,432.0 | 55.2 |
| Total | | | 4,513 | 80,069.4 | 17.7 | 3,492 | 64,290.1 | 18.4 |

Table XV in some respects bears out other findings as to the superior hardihood of the female sex. It will be noticed that the female's superior vitality is shown in all the cases where the food supply is abnormal. Nevertheless, it is noticeable that in the case of weevils fed on squares and bolls the males had the greater longevity.

### CANNIBALISM.[1]

It is hardly proper to speak of cannibalism as a food habit of the boll weevil, but the facts observed may well be recorded here. Under the impulse of extreme hunger weevils have several times showed a slight cannibalistic tendency.

Seven beetles were confined in a pill box without food. On the third day six only were alive. Of the seventh only the hardest chitinized parts (head, proboscis, pronotum, legs, and elytra) remained, the softer parts having been eaten by the survivors.

In another box containing 12 adults the leaf supplied for food was insufficient, and on the fourth day eight were dead, four were partly eaten, and others had lost one or more legs each.

In another case a few young adults and a number of squares containing pupæ were placed in a box together with a few fresh squares to serve as food for the adults. When the box was opened after a number of days one adult was found having its elytra eaten through and most of its abdomen devoured. In spite of this mutilation the victim was still alive and kicking slowly. The squares were still fresh and fit for food, so that this is really the clearest case of cannibalism observed.

Frequently more than one larva hatches in a square, and when this is the case a struggle between them is almost certain to take place before they become full grown. Many cases have been observed in which squares contained one living and one or more smaller dead larvæ, while in a few cases the actual death struggle was observed.

[1] From Bulletin 51, Bureau of Entomology, p. 48.

## SEASONAL PROPORTION OF SEXES.

The most careful records of the sexes have been made in connection with the hibernation period. The records are presented herewith in tabular form, grouping the specimens as hibernated weevils, reared weevils taken during the spring and summer, and autumn weevils which were about to hibernate:

TABLE XVI.—*Sex of hibernated boll weevils.*

| Year. | Locality. | Male. | | Female. | |
|---|---|---|---|---|---|
| | | Number. | Per cent. | Number. | Per cent. |
| 1902-03 | Victoria, Tex | 269 | 60.8 | 174 | 39.2 |
| 1903-04 | Calvert, Tex | 40 | 59.7 | 27 | 40.3 |
| 1903-04 | Victoria, Tex | 203 | 57.1 | 153 | 42.9 |
| 1905-06 | Dallas, Tex | 173 | 57.7 | 127 | 42.3 |
| 1905-06 | Victoria, Tex | 84 | 59.6 | 57 | 40.4 |
| 1906-07 | Dallas, Tex | 1,668 | 54.1 | 1,412 | 45.9 |
| 1906-07 | Calvert, Tex | 948 | 52.9 | 846 | 47.1 |
| 1906-07 | Victoria, Tex | 1,660 | 61.3 | 1,049 | 38.7 |
| Total | | 5,045 | | 3,845 | |
| Weighted averages | | | 56.8 | | 43.2 |

TABLE XVII.—*Sex of spring and summer reared boll weevils.*

| Year. | Locality. | Male. | | Female. | |
|---|---|---|---|---|---|
| | | Number. | Per cent. | Number. | Per cent. |
| 1902 | Victoria, Tex | 240 | 48.0 | 260 | 52.0 |
| 1903 | do | 140 | 53.1 | 124 | 46.9 |
| 1906 | Dallas, Tex | 63 | 44.7 | 78 | 55.3 |
| 1907 | Overton, Tex | 9 | 47.4 | 10 | 52.6 |
| 1910 | Tallulah, La | 475 | 54.7 | 393 | 45.3 |
| Total | | 927 | | 865 | |
| Weighted average | | | 51.7 | | 48.3 |

TABLE XVIII.—*Sex of autumn boll weevils ready to enter hibernation.*

| Year. | Male. | | Female. | |
|---|---|---|---|---|
| | Number. | Per cent. | Number. | Per cent. |
| 1904 | 557 | 63.7 | 317 | 36.3 |
| 1904 | 31 | 62.0 | 19 | 38.0 |
| 1905 | 63 | 57.7 | 127 | 42.3 |
| 1906 | 173 | 68.9 | 78 | 31.1 |
| 1906 | 173 | 57.7 | 127 | 42.3 |
| 1906 | 19 | 57.6 | 14 | 42.4 |
| 1906 | 29 | 52.7 | 26 | 47.3 |
| Total | 1,045 | | 708 | |
| Weighted average | | 60.0 | | 40.0 |
| Total and weighted average for all seasons | 7,017 | 57.2 | 5,418 | 42.8 |

From these determinations it appears that males are somewhat more numerous than females, the percentage based on our observations being 57.2 males to 42.8 females. It is noticeable also that the males are in preponderance throughout the year. Since the males are less active in their movements than are the females, the advantage of the existence of the majority of males becomes apparent. The larger number of males and the more active habits of the females serve to increase the chances for the meeting of the sexes.

It has been shown by rearing experiments conducted at low temperatures that the retardation of the development, such as is due to cold weather, favors the development of the males.

## FERTILIZATION.

### AGE AT BEGINNING OF COPULATION.

After the adult weevils have left the squares a certain period of feeding is necessary before they arrive at full sexual maturity. This period varies in length according to the temperature prevailing and appears to bear about the same ratio to the developmental period as does the pupal stage. With weevils fed upon leaves alone the period preceding copulation is about twice the normal length, in the cases observed, of those having squares to feed upon. Mr. Cushman, in observations at Tallulah, La., in 1910, found that the period from emergence of the female to copulation varied from two to seven days, with an average of 4.4 days. During hot weather it is probable that this period averages three or four days, but as the weather becomes colder it increases gradually until the weevils may become adult, feed for a time, and go into hibernation without having mated. It should not be understood, however, that weevils do not usually copulate before hibernation. Mr. C. E. Hood made numerous observations of the exercise of this function in the fall of 1909 at Mansura, La.

### SEXUAL ATTRACTION AND DURATION OF COPULATION.

The distance through which the attraction of the female insect will influence the male varies extremely. In observations made by Dr. Hinds at Victoria, Tex., it was found that the male was unable to recognize the female at a much greater distance than an inch. Observations carried on in the field, as well as in the laboratory, tend to show that the sexes are attracted only when they meet, as they are likely to do either on the stems or upon the squares of the plant.

In a considerable number of cases that were timed the average duration of the sexual act was very nearly 30 minutes. The earliest spring records of copulation available are for April 15.

### DURATION OF FERTILITY.

A number of females which were known to have mated were isolated to determine the duration of fertility. Although the limit was not determined exactly, the results proved very striking. Several of the females laid over 225 eggs each, and nearly all of them proved fertile. Selecting three cases in which the facts are positively known, it appears that fertility lasted for an average of something over 66 days

and that during this period these females deposited an average of nearly 200 eggs. The maximum limits may possibly be considerably higher. In fact, a single union seems to insure the fertility of as many eggs as the average female will lay, and its potency certainly lasts for a period fully equal to the average duration of life. It is probable, however, that there are many cases of repeated fertilization of females.

#### PARTHENOGENESIS.

Several series of experiments were conducted at Dallas, Tex., in August, 1906, to determine whether the boll weevil can reproduce parthenogenetically. Mr. R. A. Cushman kept 24 unfertilized females in confinement for 259 weevil days, and found that they deposited only 43 eggs, all being placed outside of the squares. No fertile eggs were laid. The rate of oviposition was one egg per female every six days. With a similar purpose Dr. Hinds isolated 40 individuals as soon as they matured.[1] Each beetle was supplied daily with fresh, clean squares and careful watch was kept for eggs. The first point noticed was that no eggs were found till the weevils were about twice as old as females usually are when they deposit their first eggs. After they began to oviposit it was found that a very small proportion of the eggs were deposited in the usual manner within sealed cavities in the squares, but nearly all of them had been left on the surface, usually near the opening of an empty egg puncture. This same habit was shown by a number of females, and so can not be ascribed to the possible physical weakness of the individuals tested. The number of eggs deposited was unusually small, and the few placed in sealed cavities failed to hatch. After somewhat more than a month had been passed in isolation a few pairs were mated to see if any change in the manner of oviposition would result. The very next eggs deposited by these fertilized females were placed in the squares and the cavities sealed up in the usual manner, showing that the infertile condition had been the cause of the abnormal manner of oviposition.

### OVIPOSITION.

#### AGE AT BEGINNING OF OVIPOSITION.

As has been shown, normal oviposition never takes place until after fertilization has been accomplished, but it usually begins soon afterwards. Observations upon the age at which the first eggs are deposited can be made more easily and more positively than those upon the age at which fertilization takes place. In a general way, therefore, the observations here given may be cited as also throwing light upon the time of beginning copulation. Table XIX is introduced to summarize the various observations which have been made upon the period preceding oviposition. It will be noticed that the range is from 4 to 14 days during the breeding season. Of course, the weevils which hibernate before ovipositing are not to be considered as of this category.

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[1] Bulletin 51, Bureau of Entomology, pp. 91, 92.

TABLE XIX.—*Age of the boll weevil at beginning of oviposition.*

| Date adult. | Place. | Date first egg. | Number of females. | Number weevil days. | Average age. |
|---|---|---|---|---|---|
| June 8-14, 1903 | Victoria, Tex | June 16-19 | 27 | 150.0 | 5.55 |
| July 8-11, 1910 | Tallulah, La | July 14-19 | 11 | 66.0 | 6.00 |
| July 29-31, 1910 | .....do | Aug. 5-7 | 7 | 44.0 | 6.29 |
| Aug. 14-22, 1910 | .....do | Aug. 21-28 | 16 | 106.0 | 6.66 |
| Sept. 4-9, 1902 | Victoria, Tex | Sept. 16-17 | 8 | 72.5 | 9.06 |
| Sept. 10-20, 1910 | Tallulah, La | Sept. 18-Oct. 8 | 9 | 116.0 | 12.89 |
| Oct. 2, 1902 | Victoria, Tex | Oct. 16 | 4 | 56.0 | 14.00 |
| Nov. 9-11, 1902 | .....do | Nov. 16-19 | 10 | 73.0 | 7.30 |
| June 8-Nov. 11 | | June 16-Nov. 19 | 92 | 683.5 | 7.40 |

### EXAMINATION OF SQUARES BEFORE OVIPOSITION.

In the course of a great many observatious upon oviposition it was found that females almost invariably examine a square carefully before they begin a puncture for egg deposition. This examination is conducted entirely by means of senses located in the antennæ and not at all by sight. In fact, the sense of sight appears to be of comparatively small use to this weevil. In regard to the actual time spent in the work of examination before beginning a puncture, over sixty observations are recorded. These show that the average time is over two minutes. This examination of squares is made by females only when they intend to oviposit. Males have never been observed acting in this way, nor do females generally do so when their only object is to feed.

### SELECTION OF UNINFESTED SQUARES FOR OVIPOSITION.

The sense by which the weevil examines the squares frequently enables it to detect an infested condition when no external sign is visible. Females sometimes refrain from placing eggs in squares, even when they are apparently searching for a place to oviposit and anxious to do so. The acuteness and accuracy of the preliminary examination is well shown by the fact that when provided with more squares than they have eggs to deposit they do not often place more than one egg in a square. Where a totally infested condition is reached, as is frequently the case in the field, no choice between infested and uninfested squares could be exercised, and then, unless the female happens to be in a condition to refrain from oviposition, she is forced to deposit more than one egg in a square. Table XX illustrates the distribution of egg and feeding puncture as collated from many records.

TABLE XX.—*Selection of squares and relation of feeding to oviposition of the boll weevil.*

| Place and time of observation. | Total squares attacked. | Squares with 1 egg each. | | Squares with more than 1 egg each. | | Squares with both egg and feeding punctures. | | Squares fed on only. | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number. | Per cent of total squares. | Number. | Per cent of total squares. | Number. | Per cent of total squares. | Number. | Per cent of total squares. |
| In laboratory, 1902 | 630 | 477 | 75.7 | 19 | 3.0 | 24 | 3.8 | 110 | 17.4 |
| In field, 1902 | 151 | 56 | 37.0 | 33 | 21.8 | 46 | 30.4 | 16 | 10.5 |
| In field, 1903 | 560 | 317 | 55.9 | 83 | 14.8 | 50 | 8.9 | 110 | 19.6 |
| In field, 1905 | 1,036 | 531 | 51.2 | 415 | 40.0 | 90 | 8.6 | 0 | 0.0 |
| In field, 1907 | 2,679 | 413 | 15.4 | 0 | 0.0 | 1,832 | 68.4 | 434 | 16.2 |
| Total | 5,056 | 1,794 | | 550 | | 2,042 | | 670 | |
| Average percentage | | | 35.4 | | 10.8 | | 40.3 | | 13.2 |

The observations show that 86.7 per cent of all squares attacked received eggs. It may also be seen that 40.9 per cent of all squares oviposited in received only one egg each. The squares which were only fed upon formed but 13.2 per cent of the total number attacked, and, as has been shown above, those receiving both egg and feeding punctures constituted 40.3 per cent. As the weevil injury overtakes the production of squares the proportion of squares containing both egg and feeding punctures increases rapidly. Where several eggs are placed in a square it is rarely the case that more than one larva develops.[1] If two or more hatch in a square one is likely to destroy the others when their feeding brings them together. Should eggs be placed in squares which already contain a partly grown larva, those hatching would probably find the quality of the food so poor that they would soon die without having made much growth. Since one egg will insure the destruction of the square and a number of eggs would do no more, it is plain that the possible number of offspring of a single female is increased directly in proportion to the number of her eggs that she places one in a square. Favorable food conditions for the larva are likewise best maintained by the avoidance of feeding upon squares in which eggs have been deposited and also by refraining from ovipositing in squares which have been much fed upon. Selection of uninfested squares is, therefore, of the greatest importance in the reproduction of the weevil, since this insures the most favorable conditions for the maturity of the largest possible number of offspring.

Feeding and oviposition are common in the same boll, but unless the infestation is very heavy it appears that only rarely is more than one egg placed in one lock, though several are often deposited in the same boll. The number deposited depends considerably upon the size of the boll. The smallest, which have just set, receive but one, as do the squares, and these fall and produce the adult weevil at about the same period as in the case of squares. Bolls which are larger when they become infested have often been found to be thickly punctured and to contain 6 or 8, and in one case 15, larvæ. (See Pl. VI, *d;* Pl. VII, *c.*)

#### DEPENDENCE OF REPRODUCTION UPON FOOD OBTAINED FROM SQUARES.[2]

During the fall of 1902 a series of experiments, lasting for 12 weeks, was made to determine the length of life of weevils fed solely upon leaves. In one lot, consisting of nine males and eight females, the average length of life of the females was 25 days, while that of the males was 36 days. Though this period far exceeded the normal time usually passed between the emergence of adults and the beginning of egg deposition, no eggs were found. Dissection of the females which lived longest showed that their ovaries were still in latent condition, though the weevils were then 81 days old. Few instances of copulation were observed among weevils fed upon leaves alone, and among nearly 70 weevils which were thus tested no eggs were ever deposited. After a period of three weeks upon leaves, 11 weevils were transferred to squares. Females in this lot began to lay in four days, and four of them deposited 323 eggs in an average time

[1] In one case four normal pupæ were found in a single square. This observation was made at Shreveport, La., by Mr. H. Pinkus.
[2] From Bull. 51, Bureau of Entomology, pp. 112, 113.

of 20 days. The conclusion seems plain that so long as leaves alone are fed upon, eggs do not develop, while a diet of squares leads to the development of eggs in about four days. It is worthy of note that the interval between the first feeding upon squares and the deposition of the first eggs is almost the same with these weevils taken in middle life as with weevils which have just emerged.

An examination of hibernated females taken in the spring of 1903, which had fed for six weeks upon cotton leaves, showed that their ovaries were still latent. Copulation was rarely observed among hibernated weevils until after squares had been given them. In a few days after feeding upon squares, mating and oviposition began. The average period was from three to five days, and, having once begun, oviposition continued regularly.

It has been found that food passes the alimentary canal in less than 24 hours. Assimilation therefore must be very rapid. It is evident that while leaves will sustain life certain nutritive elements found only in squares are essential in the production of eggs.

These experiments were repeated in 1904 with similar results.

Upon dissecting weevils just taken from hibernation, it was found that females contained no developed eggs, but that their ovaries were in an inactive condition, similar to those of females which had fed for months entirely upon leaves during the previous fall. Upon examining females taken from stubble cotton later in the spring, but before squares had appeared, it was found that they also were in similar condition. This was also true of females kept in the laboratory from the time of emergence from hibernation until squares became abundant, with only leaves for food. It seems peculiar that upon a purely leaf diet eggs are not developed, but all observations made indicate that this is the case. It can not be said definitely whether the females examined had been fertilized, but it is certain that they were not ready to deposit eggs.

### PLACE OF EGG DEPOSITION.

The location of egg punctures, while variable, still shows some selection on the part of the weevil. This may be due partly to the form of the squares and partly also to the size of the weevil, but whatever the explanation, the fact remains that in a majority of cases the egg puncture is made on a line about halfway between the base and the tip of the square. When so placed the egg rests either just inside the base of a petal or among the lowest anthers in the square, according to the varying thickness of the floral coverings at that point. Punctures are very rarely made below this line, though they are sometimes made nearer the tip. Almost invariably the egg puncture is started through the calyx in preference to the more tender portion of the square, where the corolla only would need to be punctured. With bolls no selection of any particular location has been found, but eggs seem to be placed in almost any portion.

### THE ACT OF OVIPOSITION.

While engaged in making egg punctures, the favorite position of the weevil is with its body parallel to the long axis of the square and its head toward the base. The tip of the weevil's body is thus brought near the apex of a medium-sized square. It may be that the position

described is especially favorable for obtaining a firm and even hold and this may have something to do with the regularity with which it is assumed. Having selected her location, the female takes a firm hold upon the sides of the square and completes her puncture while in this position.

The female begins drilling a hole by removing with the mandibles a little flake of the outer epidermis. Then, with her feet strongly braced by gnawing and pushing with an auger-like motion, she thrusts her beak into the tender portion of the square. At the bottom of the puncture she makes a small cavity by gnawing, at the same time moving about the hole with the beak as a pivot. Withdrawing her beak, she turns about with the center of her body as a pivot. This places the tip of her abdomen directly over the puncture, into which she thrusts her ovipositor. The ovipositor is protruded to the bottom of the cavity in which it appears to be firmly held in position by the two terminal papillæ and the enlarged terminal portion. Slight contractions of the abdomen occur while this insertion is being made. In a few moments much stronger contractions may be seen, and often a firmer hold is taken with the hind legs as the egg is passed from the body, and its movement may be seen as it is forced along within the ovipositor and down into the puncture. Only a few seconds are required to complete the deposition after the egg enters the opening to the cavity. Having placed the egg, the ovipositor is withdrawn, and just as the tip of it leaves the cavity a quantity of mucilaginous material, usually mixed with some solid excrement, is forced into the opening and smeared around by means of the tip of the abdomen. This seals the egg puncture, and the act of oviposition becomes complete. Sometimes the weevil fails to locate the puncture immediately with her ovipositor. In this event she searches excitedly, moving the tip of the abdomen about feeling carefully over the surface of the square. In this search, however, she never moves her front feet, apparently using the position of these as a guide to the distance through which she should search. Failing to locate the puncture in this way she again turns around and searches for it with her beak and antennæ. When the cavity has been found again the female invariably enlarges it before turning again to insert the ovipositor. If the search with the antennæ does not prove successful, the female generally makes another puncture in the same manner as at first.

The usual habit of the female in puncturing through the calyx enables it to seal the wound more thoroughly because of the healing power possessed by the calyx tissue. Punctures made in the corolla must remain open or are closed only by the slight filling of mucilaginous excrement by the weevil. Punctures through the calyx will, in most cases, be healed by the natural outgrowth of the tissue so as completely to fill the wounds in a manner analogous to the healing of wounds in the bark of a tree. The custom of the weevil in sealing up its egg punctures with a mixture of mucous substance and excrement is of great advantage and assistance to the plant in the healing process. While undoubtedly applied primarily as a protection to the egg, it serves to keep the punctured tissues from drying and decay, and thus promotes the process of repair. As a result of the growth thus stimulated in the calyx, the wound is healed perfectly in a short

time, and a corky outgrowth appears above the general surface plane. This prominence has been termed a "wart." The healing is completed even before the hatching of the egg takes place, and thus both egg and larva partake of the benefit of its production. Occasionally warts develop from feeding punctures which were small, but the exact conditions under which this takes place have not been determined. Nevertheless, the presence of warts is the most certain external indication of oviposition in squares. In a series of observations they were found to follow oviposition in 84 per cent of the cases.

### TIME REQUIRED TO DEPOSIT AN EGG.

Careful observations have been made upon the time of egg deposition. As in all other processes of the life history of this insect, the period of egg deposition is influenced by climatic conditions. It was found at Tallulah, La., in the early part of the summer of 1910, that the time required for making the puncture varied from 1 minute and 20 seconds to 8 minutes and 27 seconds, with an average of 3 minutes and 36 seconds. On the other hand, at Victoria, Tex., in October, the average time was 5¼ minutes, and the range from 1 to 13 minutes. At Tallulah the period for the deposition of the egg and the sealing of the puncture varied from 2 minutes and 45 seconds to 9 minutes and 30 seconds, with an average of 4 minutes and 41 seconds. At Victoria the period ranged from 3 to 16 minutes and averaged 7½ minutes.

### STIMULATING EFFECT OF ABUNDANCE OF SQUARES UPON EGG DEPOSITION.[1]

Four actively laying females were confined together upon a few squares from September 22 to October 14, 1902. During this period they laid a total of 227 eggs, or an average of 2.37 eggs per weevil per day. For the next 13 days these same weevils were isolated and supplied with an abundance of squares. During this shorter period they laid 236 eggs, or 4.54 eggs per female daily.

These figures are the more striking, because the stimulation was plainly shown in spite of the general tendency to lay fewer eggs as the weevils grow older and as the average temperature becomes lower.

### ACTIVITY OF WEEVILS IN DIFFERENT PARTS OF THE DAY.

Two series of observations have been carried on to determine the hourly activity of the weevils. The experiments at Victoria were conducted in the early part of September, when the temperature was ranging from a little under 70° F. to 95° F. during the day. It was found that there was almost a perfect coincidence between the temperature curve and the curve of the average activity of the females in ovipositing. This is shown in the accompanying diagram (fig. 5).

It also appeared that the activity of the weevils began and ceased at about 75° F. Perhaps this indicates that the act of oviposition requires a zero of effective temperature different from that of development. This would be entirely analogous to conditions in flowers, where it is found that the various functions of the plant are governed

[1] Modified from Bulletin 51, Bureau of Entomology, pp. 87, 88.

by independent laws of effective temperature. It appears also that the activity is much less on cloudy days than on clear days. At Tallulah, La., in 1910, observations were made on the periodic division of daily oviposition. The results are shown in Table XXI.

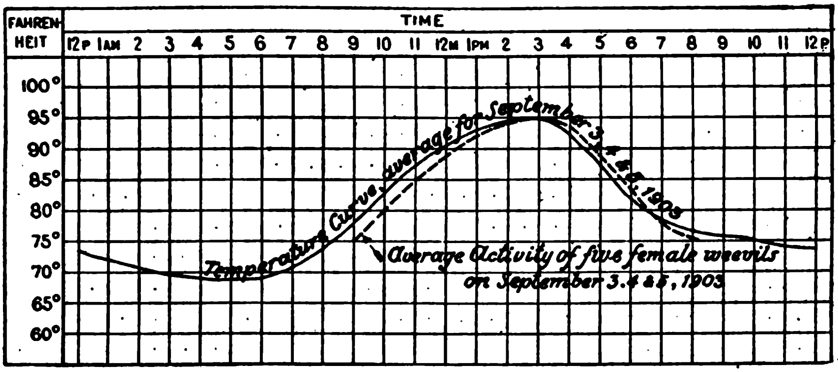



FIG. 5.—Diagram showing average activity of five female boll weevils. (After Hunter and Hinds.)

TABLE XXI.—*Summary of periodic division of oviposition, based upon nine boll weevils, Tallulah, La., July, 1910.*[1]

| Period. | Total eggs laid. | Average number of eggs per hour. | Per cent of total oviposition in each period. | Average eggs per weevil per hour. |
|---|---|---|---|---|
| 5 p. m.-7.30 p. m. | 25 | 5.00 | 23.15 | 0.63 |
| 7.30 p. m.-4 a. m. | 10 | .59 | 9.26 | .07 |
| 4 a. m.-9 a. m. | 21 | 2.10 | 19.44 | .26 |
| 9 a. m.-1 p. m. | 17 | 2.13 | 15.74 | .27 |
| 1 p. m.-5 p. m. | 35 | 4.38 | 32.41 | .55 |

From these records it may be seen that the warmest part of the day is the most active period for the weevils.

### SEASONAL RATE OF OVIPOSITION.

Since the period of reproductive activity of the boll weevil is so long, the rate at which eggs are deposited is a question requiring much time for its determination. The rate of oviposition is at least as strongly influenced by variations in temperature as is the rate of development, and it is very probable that some of the previously unaccountable and abrupt variations in the rate upon succeeding days may be explained by the relative humidity or by the amount of sunshine. The rate is influenced also by the abundance of clean squares which the weevil can find, so that it is greater in the early part of the season as the degree of infestation is approaching its limit than after infestation has reached its maximum. Several series of observations have been made upon the rate of egg deposition. These have been tabulated below in Table XXII.

[1] From Cushman, Journ. Econ. Ent., vol. 4, p. 436.

TABLE XXII.—*Seasonal rate of oviposition of the boll weevil.*

| Place. | Time. | Number of females. | Number of weevil days. | Average period of oviposition. | Total number of eggs. | Average number of eggs daily. | Average total number per female. | Maximum number in one day. |
|---|---|---|---|---|---|---|---|---|
| Victoria, Tex. | Aug.-Dec., 1902 | [3] 1 | 135 | 135 | 255 | 1.88 | 255.0 | ........ |
| Do. | Sept.-Oct., 1902 | 40 | 247 | 6 | 1,248 | 5.05 | 31.2 | ........ |
| Do. | ....do.... | 4 | {23<br>13} | 9 | {227<br>236 | 2.37<br>4.54} | 116.0 | ........ |
| Do. | Oct.-Dec., 1902 | 9 | 352 | 39 | 990 | 2.81 | 110.0 | ........ |
| Do.[1] | May-July, 1903 | [3] 51 | 2,018 | 39 | 5,254 | 2.60 | 103.0 | 18 |
| Do.[2] | June-Sept., 1903 | [3] 24 | 1,396 | 58 | 3,541 | 2.53 | 147.5 | ........ |
| Do. | Aug., 1904 | 3 | 21 | 7 | 112 | 5.32 | 37.3 | ........ |
| Terrell, Tex. | Sept., 1904 | 4 | 12 | 3 | 55 | 4.56 | 13.7 | ........ |
| Dallas, Tex. | July-Aug., 1905 | 2 | 23 | 11 | 81 | 3.68 | 40.5 | 8 |
| Do. | Aug.-Sept., 1905 | 3 | 108 | 36 | 233 | 2.15 | 77.6 | 20 |
| Tallulah, La.[1] | June-Aug., 1910 | [3] 9 | 310 | 34 | 1,830 | 5.90 | 203.3 | 20 |
| Do.[2] | Aug.-Oct., 1910 | [3] 4 | 183 | 45 | 887 | 4.85 | 221.7 | 12 |
| Total | ........ | 154 | 4,840 | ........ | 14,949 | ........ | ........ | 20 |
| Average | ........ | ........ | ........ | 31 | ........ | 3.13 | 97.07 | ........ |

[1] Hibernated weevils.
[2] First generation weevils.
[3] Observed for entire oviposition period and used in discussion of fecundity.

The influence of temperature upon the rate of oviposition may be shown by the following diagram (fig. 6), which expresses in a single line the mean number of eggs laid daily at a given temperature. There is, of course, more or less fluctuation from the mean, and it is due mostly to differences in humidity.

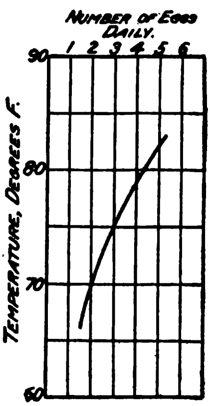



FIG. 6.—Diagram to illustrate influence of temperature on average rate of oviposition of boll weevil. (Original.)

The maximum number of eggs deposited by any weevil in one day has been recorded by Mr. Cushman as 20 at Tallulah, La. At Victoria, Tex., Dr. Morrill recorded two weevils to have laid 108 eggs in three days, or at the rate of 18 eggs per day. Dr. Morrill found that the size of weevils did not affect the rate per day, as four very small females laid 761 eggs at the rate of 3.3 eggs per day. It will be noticed that this rate is higher than the average of all the records in Table XXII. The number of eggs produced on the first day of oviposition varies from one to seven. About 67 per cent of the weevils at Victoria were found to oviposit fewer than three eggs on the first day.

IS THE FECUNDITY OF THE WEEVIL DECREASING?

In view of the fact that recent observations have shown a decrease in the fecundity of the gipsy moth in Massachusetts,[1] we have selected from the foregoing table (Table XXII) on the seasonal rate of oviposition the rather meager data bearing on the question of whether the fecundity of the boll weevil is decreasing. We find 76

[1] Howard and Fiske, Bull. 91, Bur. Ent., U. S. Dept. Agr., pp. 109, 110, 1911.

weevils at Victoria, Tex., in 1902 and 1903, laying an average of 119 eggs in an average period of 46 days, and at the rate of 2.6 eggs per day, with a maximum of 18 eggs in one day; while at Tallulah, La., in 1910, 13 weevils laid an average of 209 eggs in an average period of 37 days and at the rate of 5.7 eggs per day, with a maximum of 20 eggs in one day. While these facts appear to indicate that the fecundity of the weevil is not decreasing, they do not, on the other hand, because of the great difference in the places of observations, prove an increase. More detailed data will be obtained on this point in the future.

### PERIOD OF OVIPOSITION.

With the exception of hibernated weevils it appears that oviposition begins with the majority of females in about seven days after they emerge as adults to feed and continues uninterruptedly until shortly before death. In the case of 43 weevils observed at Tallulah, La., in 1910, the average preoviposition period was 7.72 days, the minimum 5, and the maximum 23 days. While females frequently deposit their last eggs during the last day of their life, a period of a few days usually intervenes between the cessation of oviposition and death.

The known maximum number of eggs laid by a single individual is 304. This was in the case of a weevil which lived for 275 days and deposited eggs at the rate of 7.6 eggs per day for 41 days. The maximum period of oviposition recorded is 135 days. In the case of 52 hibernated weevils at Victoria the period of oviposition averaged about 48 days, the maximum being fully 92 days. In an average rate with 21 females in the first generation the actual period was almost 75 days, the maximum being 113 days. The average period for the females of the first two generations appears to be longer than that for any other. In the third generation the average period for 11 females was 58 days, the maximum being 99 days, and in the fifth generation for 5 females the period averaged 48 days, with the maximum only 62 days. At Tallulah, La., in 1910, the average oviposition period was found to be 34.44 days. The average period for all of the records available is but 31 days.

The approach of cold weather cuts short the activity of the weevils which become adult after the middle of August, thereby decreasing the length of their oviposition period. Weevils which pass through the winter usually live longest, but as it requires more or less vitality to pass through the long hibernation period, their activity in the spring is thereby lessened.

### EFFECTS OF OVIPOSITION UPON SQUARES.

As has been explained elsewhere, the attack of the weevil on the square causes it to form an absciss layer, which ultimately causes it to separate entirely from the plant. One of the immediate effects of attack is the flaring of the square, that is, the spreading of the bracts and their subsequent yellowing and drying. (See Pl. I.) Flaring may result from many other causes besides boll-weevil injury. When resulting from weevil injury it does not begin, as a rule, immediately after the injury, but only within from one to three days of the time

when the square will be ready to fall. In especially severe cases of feeding injury flaring often results in less than 24 hours. Occasionally the growth of the square overcomes the injury from feeding, and the bracts, after having flared, again close up and the square continues its normal development and forms a perfect boll. When injured by the feeding of a young larva as the direct result of successful oviposition, flaring was found in 193 cases to take place in an average of 7 days from the deposition of the egg. (See Pls. V, VI.)

After an average period of 2.5 days subsequent to flaring the square was found to fall to the ground, although it may sometimes hang by a thread of the bark. The average time from egg deposition to the falling of the square in 539 cases from June to September was found to be about 9.6 days, which is about the middle point of the weevil development. It has been shown in another place (Table XXVII) that the period before the falling of the square has a direct bearing upon the period of the development of the weevil.

### PROBABLE ORIGINAL BREEDING HABIT.

There is nothing to indicate that the boll weevil has changed its food plant, although it may have done so. It is now confined, as far as we know, to the various species and varieties of the genus Gossypium. The boll weevil belongs to a genus of weevils every species of which is confined in its food habits to a single species or genus of food plants. The majority of the species of Anthonomus and perhaps all that belong to the true genus normally breed in buds. It is therefore reasonable to assume that the normal habit of the boll weevil is to breed in the cotton buds or "squares," and that its habit of breeding in the bolls is an adaptation due to the necessity of providing for the great number of weevils which develop in the later part of the season. A study of the length of the development of many species of Anthonomus leads the authors to believe that the short developmental period in squares is perfectly normal and that the longer period in bolls is due merely to environmental conditions, as is explained under the subject of development.

## THE EGG.

### DURATION OF EGG STAGE.

Concealed as the eggs are beneath several layers of vegetable tissue, it is impossible to examine them to ascertain the exact length of the egg stage without in some degree interfering with the naturalness of their surroundings. The beginning of the stage is easily obtained by confining female weevils with uninfested squares. By making a large series of observations about the time that the larvæ should hatch it is possible to obtain the average length of the egg stage. The extreme range which has been observed in the duration of this stage is from 1 to 17 days, while the average period for the whole number of observations is but 3.7 days. It is possible that the embryo can undergo an even greater retardation without losing its vitality. The period of embryonic development is lengthened by decreases in the temperature and also by lowered atmospheric humidity. Thus it was found that between 79° F. and 81° F. the

egg stage averaged 1.9 days at Alexandria, La., 2.61 days at Tallulah, La., 3.73 days at Victoria, Tex., and 4.1 days at Dallas, these differences corresponding quite regularly to the differences in the humidity of the various places. Table XXIII is presented to show the data

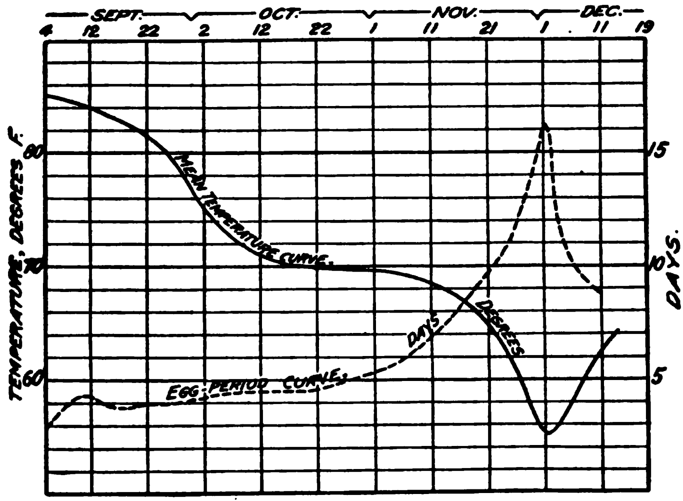



FIG. 7.—Diagram illustrating relationship of temperature to the egg period of the boll weevil at Victoria, Tex., in 1902. (Original.)

which have been obtained on this stage, and is accompanied by two diagrams (figs. 7 and 8) to illustrate the relationship between mean temperature and the length of the egg period.

TABLE XXIII.—*Duration of the egg stage of the boll weevil.*

| Place. | Year. | Eggs laid. | Eggs hatched. | Number of eggs laid. | Total number of egg days. | Average period. | Mean temperature. |
|---|---|---|---|---|---|---|---|
| | | | | | | *Days.* | ° *F.* |
| Victoria, Tex | 1902 | Sept. 4-29 | Sept. 7-Oct. 3 | 384 | 1,434 | 3.73 | 81.0 |
| Do | 1902 | Oct. 7-20 | Oct. 11-24 | 95 | 430 | 4.52 | 73.0 |
| Do | 1902 | Nov. 7 | Nov. 13 | 12 | 72 | 6.0 | ........ |
| Do | 1902 | Nov. 24-28 | Dec. 5-15 | 17 | 214 | 12.59 | 62.0 |
| Do | 1902 | Dec. 2-9 | Dec. 15-18 | 19 | 264 | 13.9 | ........ |
| Do | 1903 | May 27-June 5 | May 30-June 9 | 25 | 93 | 3.75 | 72.5 |
| Alexandria, La | 1907 | Aug. 31-Sept. 5 | Sept. 2-7 | 229 | 436 | 1.9 | 79.2 |
| Dallas, Tex | 1908 | July 17-20 | July 20-23 | 35 | 145 | 4.1 | 81.6 |
| Do | 1908 | Aug. 14 | Aug. 17 | 11 | 33 | 3.0 | 88.0 |
| Tallulah, La | 1910 | June 27-July 10 | July 1-12 | 44 | 115 | 2.61 | 78.9 |
| Total | ........ | ........ | ........ | 871 | 3,236 | ........ | ........ |
| Average | ........ | ........ | ........ | ........ | ........ | 3.7 | 74.6 |

### HATCHING.

While still within the egg the larva can be seen to work its mandibles vigorously, and although a larva has never been seen in the act of making the rupture which allows it to escape from the egg, it is believed that the rupture is first started by the mandibles. The larvæ do not seem to eat the membranes from which they have escaped, but owing to the extreme delicacy of the skin it is almost impossible to find any trace of it after the larva has left it and begun feeding on the square, the membranes having been found in only a few cases.

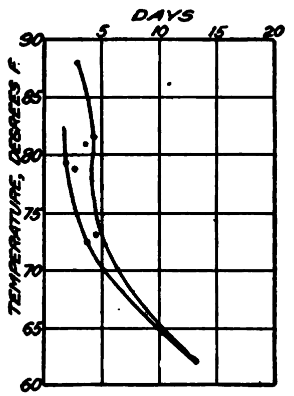


Fig. 8.—Diagram illustrating relationship of temperature to the egg period of the boll weevil and showing variations due to humidity. (Original.)

### HATCHING OF EGGS LAID OUTSIDE OF COTTON FRUIT.

It occasionally happens that a female is unable to force an egg into the puncture prepared to receive it, and the egg is laid on the outside of the square or boll. Eggs so placed usually shrivel and dry up within a short time. To test the possibility of a larva making its way into the square from the outside a number were protected from drying. Of the 19 eggs tested, 6 hatched in from two to three days. In no case, however, was the young larva able to make its way into the square, and it soon perished. The hatching of eggs laid outside, therefore, appears to be of no importance, since the larvæ must perish without doing any damage.

On August 23, 1906, Mr. R. A. Cushman observed the hatching of two larvæ under water from eggs which had been submerged over 24 hours.

### EATING OF EGGS DEPOSITED OUTSIDE.

The number of eggs left outside increases as the female becomes weakened and is especially noticeable shortly before her death. Repeated observations have shown that unfertilized females generally deposit their eggs on the outside, and only occasionally is an infertile egg deposited normally, though the attempt is regularly made to do so. The number of such eggs which may be found is greatly decreased by a peculiar habit observed many times, which will be described. Occasionally it appeared that the puncture which the female had made for the reception of an egg was too narrow to receive it, and after a prolonged attempt to force it down the female would withdraw her ovipositor, leaving the egg at the surface. She would then turn immediately and devour the egg. In some cases more than one has been devoured after repeated failures to place them properly in the squares.

### PERCENTAGE OF EGGS THAT HATCH.

Definite records have not been kept regarding the percentage of eggs that hatch, but in the many hundreds of eggs followed during these observations very few have failed to hatch. Though some are much slower in embryonic development than are others laid at the same time and by the same female, it is probable that less than 1 per cent of the eggs are infertile or fail to hatch. It must be considered, however, that proliferation crushes many eggs. This proliferation is most aggressive against the eggs in the bolls in the late fall.

## THE LARVA.

### FOOD HABITS.[1]

It is plainly the instinct of the mother weevil to deposit her egg so that the larva upon hatching will find itself surrounded by an abundance of favorable food. In the great majority of cases this food consists principally of immature pollen. This is the first food of the larva which develops in a square, and it must be both soft and nutritious. Often a larva will eat its way entirely around the inside of a square in its pursuit of this food. In most cases the larva is about half grown before it feeds to any extent upon the other portions of the square. It may then take the pistil and the central portion of the ovary, scooping out a smoothly rounded cavity for the accommodation of its rapidly increasing bulk. So rapidly does the larva feed and grow that in rather less than a week it has devoured two or three times the bulk of its own body when fully grown. It sometimes happens that the square is large when the egg is deposited therein, and the bloom begins to open before the injury done by the larva becomes sufficient to arrest its development. In many cases of this kind the larva works its way up into the corolla and falls with it when it is shed, leaving the young boll quite untouched. Occasionally the flower opens and fertilization is accomplished before any injury is done the pistil, and in rare cases a perfect boll results from an infested square. Sometimes the larva when small works its way down into the ovary before the bloom falls, and in such cases the small boll falls as would a square. (See Pl. VI, *a*, *b*, *d*.)

In large bolls the larvæ feed principally upon the seed and to some extent upon the immature fiber. A larva will usually destroy only one lock in a boll, though two are sometimes injured. When the infestation is severe a number of weevils, occasionally as many as six or even more, may be developed in a single boll, which is completely destroyed by the feeding of the larvæ. (See Pl. VII, *a*, *c*.)

### GROWTH.

The rate of growth, of course, is dependent upon many external conditions. It has been found that in squares during the hot weather, the length of the body increases quite regularly by about 1 mm. a day. Full grown larvæ vary in length from 5 to 10 mm. across the tips of the curve. Larvæ of normal size in squares average from 6 to 7 mm. The largest larvæ are developed in bolls which grow to maturity.

[1] From Bulletin 51, Bureau of Entomology, p. 49.

### MOLTS.

To accommodate the rapid growth of the larvæ two or three molts occur. The first occurs at about the second day, and the second at about the fourth day. Whether a third molt occurs before pupation can not be positively stated, but having occasionally found larvæ which had certainly just molted, but which were not larger than the usual size of the second molt, we are led to suspect that three larval molts may sometimes occur, though possibly not always. In bolls where the length of the larval stage is often three or four times as great as that usually passed in squares, it seems almost certain that more than two larval molts occur regularly.

According to Dr. Hinds's observations the skin splits along the back, starting at the neck, and is then pushed downward and backward along the venter of the larva. The cast head shield remains attached to the rest of the skin.

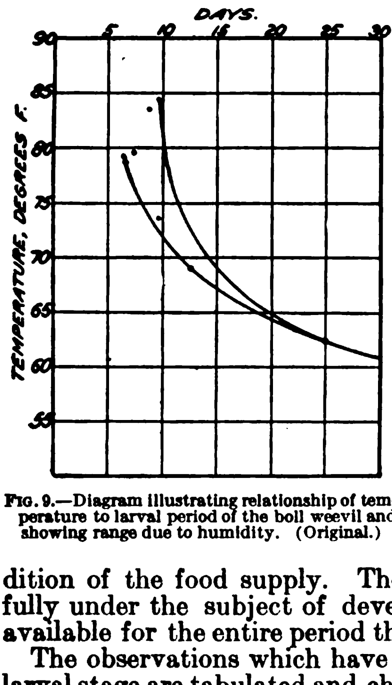



FIG. 9.—Diagram illustrating relationship of temperature to larval period of the boll weevil and showing range due to humidity. (Original.)

### DURATION OF LARVAL STAGE.

The length of the larval stage, as a rule, is about equal to the sum of that of the egg and pupal stages. It lengthens as the temperature falls and also as the amount of moisture decreases. It is also probably influenced by the nature and condition of the food supply. These influences will be discussed more fully under the subject of developmental period, as more data are available for the entire period than for any of the stages in this period.

The observations which have been made upon the duration of the larval stage are tabulated and charted below (Table XXIV and fig. 9).

TABLE XXIV.—*Duration of the larval stage of the boll weevil.*

| Place. | Year. | Hatched. | Pupated. | Number of larvæ. | Total number of larva days. | Average larval period. | Mean temperature. |
|---|---|---|---|---|---|---|---|
| | | | | | | *Days.* | °*F.* |
| Victoria, Tex. | 1902 | Sept. 6 | Oct. 5 | 195 | 1,462.5 | 7.5 | 78.7 |
| Do | 1902 | Sept. 26 | Oct. 21 | 15 | 142.5 | 9.5 | 73.6 |
| Do | 1902 | Nov. 11 | Dec. 12 | 15 | 375.0 | 25.0 | 62.5 |
| Victoria, Tex. (ice box) | 1904 | Aug. 26–Sept. 3 | | 88 | 1,100.0 | 12.5 | 69.0 |
| Alexandria, La. | 1907 | Aug. 26–Sept. 5 | Aug. 28–Sept. 7 | 149 | 1,096.0 | 7.3 | 79.9 |
| Dallas, Tex. | 1908 | July 18–29 | Aug. 1–12 | 50 | 435.5 | 8.7 | 83.7 |
| Do | 1908 | Aug. 3–19 | Aug. 17–31 | 44 | 390.0 | 8.8 | 84.1 |
| Tallulah, La. | 1910 | June 27–July 7 | July 7–17 | 98 | 618.5 | [1] 6.3 | 79.1 |
| Total | | June 27–Nov. 11 | July 7–Dec. 12 | 654 | 5,620.0 | 8.5 | 76.2 |

[1] The extremes were 5.2 and 7.3 days.

## PUPAL CELLS.

As the larva becomes larger it gradually forms about itself a hardened black cell, composed of its cast skins and excrement. This cell is of a very tough leathery nature and seems to hold its moisture for a considerable period. In bolls the cell is even harder, as it becomes more or less mixed with lint and attains a considerable firmness, which often gives the cell the hardness and appearance of a seed. These pupal cells frequently include a portion of the hull of a seed, and it has also been found that the larva sometimes forms its cell within a single cotton seed. In these cells the larva transforms to the pupal stage. (See Pl. IX.)

## PUPATION.

The formation of the adult appendages has progressed considerably before the last larval skin is cast. The wing pads appear to be nearly one-half their ultimate size. The formation of the legs is also distinctly marked, and the old head shield appears to be pushed down upon the ventral side of the thorax by the gradual elongation of the developing proboscis. Finally, the tension becomes so great that the tightly stretched skin is ruptured over the vertex of the head, and it is then gradually cast off, revealing the delicate white pupa. The cast skin frequently remains for some time attached to the tip of the abdomen. The actual period of ecdysis is about 45 minutes.

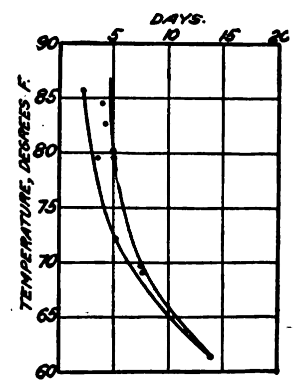



FIG. 10.—Diagram illustrating relationship between temperature and the pupal period of the boll weevil and showing variations due to humidity. (Original.)

## THE PUPA.

### ACTIVITY.

The pupal stage of the boll weevil is more or less an active stage. The pupa is so constructed, with a forked prong at the posterior tip and with two strong tubercles on the thorax, as to have an axis upon which it can revolve without injuring its more delicate appendages. As the cell is almost round, this movement of the pupa is more or less free in all directions and tends to make the cell harder and more durable. A person with acute hearing can detect the presence of a pupa by holding a square close to the ear. (See Pl. VI, *c*, *d*.)

### DURATION OF THE PUPAL STAGE.

In general, it may be said that the length of the pupal stage is about equal to that of the larval stage minus the length of the egg stage. This stage varies considerably, as do the two previous stages, the range being from 2 days at high temperature to 14 or more days at low temperature. During the winter it may be as long as several months. Table XXV and figure 10 are presented to illustrate the variations in the pupal period in their relationship to mean temperature. It may be stated briefly that the length of the pupal stage increases as the temperature decreases, and that the average humidity also influences the stage in the same manner.

TABLE XXV.—*Duration of the pupal stage of the boll weevil.*

| Place. | Year. | Pupated. | Emerged. | Number of pupæ | Total number of pupa days. | Average pupal period. | Mean temperature. |
|---|---|---|---|---|---|---|---|
| | | | | | | | *Degrees F.* |
| Victoria, Tex | 1902 | July 6–13 | July 10–16 | 27 | 97 | 3.5 | 82.65 |
| Do | do | July 12–18 | July 16–22 | 22 | 84 | 3.8 | |
| Do | do | July 18–23 | July 23–28 | 86 | 392 | 4.5 | |
| Do | do | July 24–25 | July 29–30 | 23 | 111 | 4.8 | |
| Do | do | Sept. 15 | Sept. 20 | 4 | 20 | 5 | 79.05 |
| Do | do | Oct. 21–24 | Oct. 27–28 | 5 | 24 | 4.8 | ........ |
| Do | do | Nov. 2–6 | Nov. 9–13 | 29 | 212 | 7.3 | 69.2 |
| Do | do | Dec. 2–13 | Dec. 15–29 | 4 | 56 | 14 | 61.55 |
| Victoria, Tex., ice box | do | | | 88 | 660 | 7.5 | 69 |
| Dallas, Tex | 1907 | June 13 | June 19 | 1 | 5 | 5 | 80.1 |
| Alexandria, La | do | Aug. 5 | Aug. 7–8 | 20 | 43 | 2.1 | 85.7 |
| Do | do | Sept. 10–13 | Sept. 16–18 | 141 | 717 | 5 | 72.1 |
| Dallas, Tex | 1908 | Aug. 1–6 | Aug. 5–11 | 10 | 41 | 4.1 | 84.5 |
| Tallulah, La | 1910 | July 7–17 | July 14–21 | 50 | 167.5 | [1] 3.3 | 79.1 |
| Total | 1902–1910. | June 13–Dec. 13 | June 19–Dec. 29. | 510 | 2,629.5 | 5.1 | 74.3 |

[1] The extremes were 2.8 and 3.9 days.

## PERCENTAGE OF WEEVILS DEVELOPED FROM INFESTED SQUARES.[1]

During the season of 1902 part of the many squares gathered in infested fields for the rearing of weevils were followed to learn something of the percentage which produced normal adults. No examination was made for those not yielding a weevil. The decay of the square during the period from its falling to the maximum time that must be allowed for weevils to escape normally so obliterates any small amount of work by a larva that it is difficult, even with examination, to determine accurately the number of dead small larvæ.

TABLE XXVI.—*Percentage of boll weevils from infested squares.*

| Locality. | Approximate date. | Number of squares. | Number of weevils. | Percentage of squares producing weevils. |
|---|---|---|---|---|
| | 1902. | | | |
| Victoria, Tex | July to August | 1,125 | 360 | 32.0 |
| Guadalupe, Tex | August | 387 | 108 | 28.0 |
| | 1903. | | | |
| Victoria, Tex | June | 334 | 106 | 32.0 |
| Do | June to August | 873 | 355 | 41.0 |
| Do | August to September | 368 | 192 | 52.0 |
| | 1904. | | | |
| Do | June to September | 951 | 469 | 49.3 |
| Total | | 4,038 | 1,590 | 39.4 |

It seems safe to conclude that throughout the season fully one-third of the squares which fall after receiving weevil injury may be expected to produce weevils.

[1] From Bul. 51, Bureau of Entomology, p. 92.

## LIFE CYCLE.

### DURATION OF LIFE CYCLE.

We have shown that the average duration of the egg stage under different conditions is 3.7 days, of the larva 8.5 days, of the pupa 5.1 days, of the preoviposition period 7.7 days, and of the oviposition period 31 days. Consequently, the average time from the deposition of the egg to the completion of oviposition by the resulting adult is 56 days. The average required for the combined egg, larval, and pupal stages is 17.3 days. The larva requires about 2½ times as many days as the egg, and the pupa about two-thirds of the time required for the development of the larva.

#### SEXUAL VARIATIONS.

There are several factors which govern the duration of the life cycle of the weevil. The factor which is of least importance, if, indeed, it is of any importance, is that of sex. Mr. R. A. Cushman, in experiments at Tallulah, La., in 1910, in which squares were under more or less uniform climatic conditions, found that 475 males averaged in development 13.88 days, while 393 females averaged 13.49 days. The figures are so nearly equal that there is great doubt as to whether the sexes require different periods.

#### VARIATIONS DUE TO LOCATION OF DEVELOPING STAGE.

As has been stated, the tendency of the squares to hang or fall is a determining factor in the length of the developmental stage. In a humid region, however, the difference may be very small. At Alexandria, La., in 1907, it was found that the average developmental period during the first 19 days of August in fallen squares was 15.3 days and in hanging squares was 15.1 days.

#### VARIATIONS DUE TO TIME OF FALLING OF INFESTED SQUARES.

The period preceding the falling of the squares to the ground seems to be one of the strongest factors in determining the length of the developmental stages. To illustrate this, at Victoria, Tex., in August, 1904, it was found that the average development in squares which hung only 1 day was 13 days, whereas for squares which hung 18 days, the development was 28½ days; also at Dallas, Tex., in August, 1906, the average development in squares which hung 6 days was 19 days and in squares which hung 22 days was 36 days. We present Table XXVII, which shows in general that the difference in the time required for development in hanging and in fallen squares is proportionately the same in all months of the year and at all places where observations have been made.

TABLE XXVII.—*Table to illustrate the effect of the time of falling upon the period of development of the boll weevil in squares.*

| No. of days before falling. | Average period of development of weevils for eggs laid during specified periods. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Victoria, Tex., 1904. | | | | | Dallas, Tex., 1905. | | | Dallas, Tex., 1906. | | | | Alexandria, La., 1907. |
| | June. | July 1-15. | July 15-30. | Aug. 2-11. | Sept. 10-29. | Aug. 12-28. | Sept. 11-30. | Oct. 2-3. | June 14-21. | June 29-July 6. | July 16-21. | Aug. 12-17. | July 28-Aug. 19. |
| | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* |
| 1 | | 12.0 | | 13.0 | 15.0 | | | 25.0 | | | | | 12.5 |
| 2 | | 13.5 | 13.0 | | 13.0 | 13.2 | 18.5 | | | | | | 12.6 |
| 3 | 14.4 | 14.0 | | | | 13.4 | 21.7 | | 14.5 | | 17.0 | | 12.3 |
| 4 | 14.0 | 14.4 | | 16.0 | 15.0 | 14.5 | | | 16.0 | | 15.0 | | 13.5 |
| 5 | 16.0 | 14.1 | 14.8 | | 18.0 | 14.7 | 18.7 | 18.0 | 16.3 | | 17.0 | | 14.9 |
| 6 | 18.0 | 15.6 | 17.0 | 15.0 | 19.0 | 16.0 | | 26.0 | | 17.5 | 17.0 | 19.0 | 14.9 |
| 7 | 16.6 | 15.5 | 16.0 | 16.6 | 16.6 | 16.6 | 21.2 | | 16.3 | 16.0 | 16.9 | 17.9 | 15.0 |
| 8 | 17.6 | 18.9 | 17.5 | | 18.6 | 16.6 | 28.0 | | 17.0 | 16.0 | 17.6 | 19.5 | 16.4 |
| 9 | 18.6 | 18.3 | | 19.6 | 19.5 | 19.0 | | | 16.0 | 18.5 | 18.7 | 19.5 | 18.9 |
| 10 | 30.0 | 18.7 | | 25.2 | 22.3 | 19.7 | | | | | 18.6 | 21.4 | 17.6 |
| 11 | 17.0 | 18.8 | 20.6 | 21.5 | 25.5 | | | | 18.6 | 24.0 | 19.2 | 23.4 | 21.2 |
| 12 | 23.0 | 20.8 | 21.6 | 22.1 | 22.0 | 19.5 | 28.0 | | | | 18.1 | 24.0 | |
| 13 | 19.5 | 20.0 | 22.0 | 25.2 | 22.5 | | | | 23.0 | | 19.0 | 25.0 | |
| 14 | 20.0 | | 19.0 | 26.1 | | | | | | | 20.5 | 24.8 | 18.0 |
| 15 | | 22.0 | 24.0 | 23.7 | | | | | 23.0 | | 19.0 | 25.0 | |
| 16 | | 23.0 | 23.0 | 28.5 | | | | | | | 20.0 | | |
| 17 | | | 22.0 | | | 25.0 | | 25.0 | | | | | |
| 18 | | | | 28.5 | 24.0 | | | | | | | 35.0 | |
| 19 | | | | | | | | | | | 29.0 | 36.0 | |
| 20 | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | 35.0 | |
| 22 | | | | 26.0 | | | | | | | | 36.0 | |
| Average | 17.5 | 16.8 | 18.8 | 22.0 | 18.8 | 16.2 | 21.0 | 23.5 | 18.0 | 18.3 | 18.3 | 22.3 | 15.3 |
| No. of stages | 36 | 123 | 25 | 62 | 58 | 69 | 17 | 4 | 20 | 9 | 69 | 85 | 87 |

The average for the 664 stages covered in the table is 18.4 days, which may be taken as the general average period of development in squares. Figure 11 graphically illustrates Table XXVII.

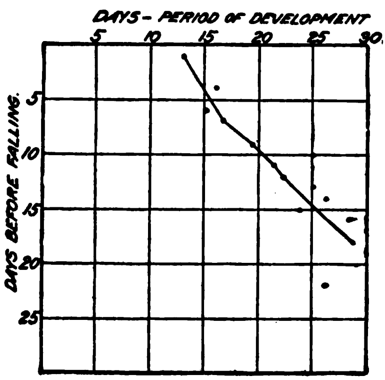



FIG. 11.—Diagram illustrating effect of time of falling of infested squares upon period of development of boll weevil at Victoria, Tex., August, 1904. (Original.)

VARIATIONS DUE TO TEMPERATURE.

It will be noticed that the average period of development in squares which have hung on the plant for the same length of time varies with the season, but an increase of temperature regularly lowers the average developmental period. The following diagram (fig. 12) has been constructed from the average curves determined for each of the stages in the development and shows that the range is from 13 days at 88° F. to 51 days at 62° F.

By using the quantities determined by the curves in figure 12 it is possible to chart the mean or normal developmental period by months for any given place with known mean temperatures. This has been done on the following diagram (fig. 13) for Victoria, Tex., Ardmore, Okla., and Vicks-

burg, Miss. The curve obtained for Victoria is the widest which can be obtained in the United States with the exception of Texas points to the south of Victoria. It is interesting, however, that

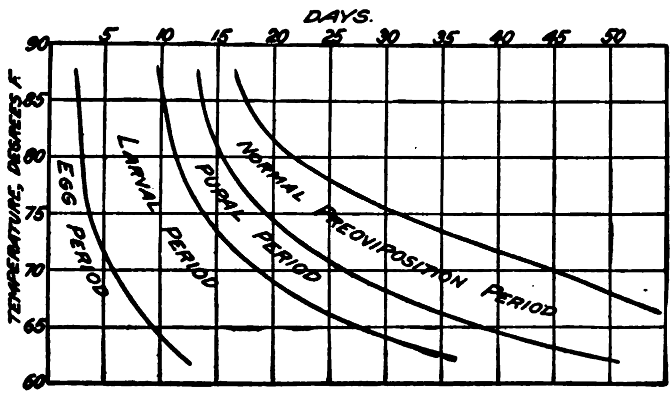



FIG. 12.—Diagram illustrating temperature control of developmental period of the boll weevil. (Original.)

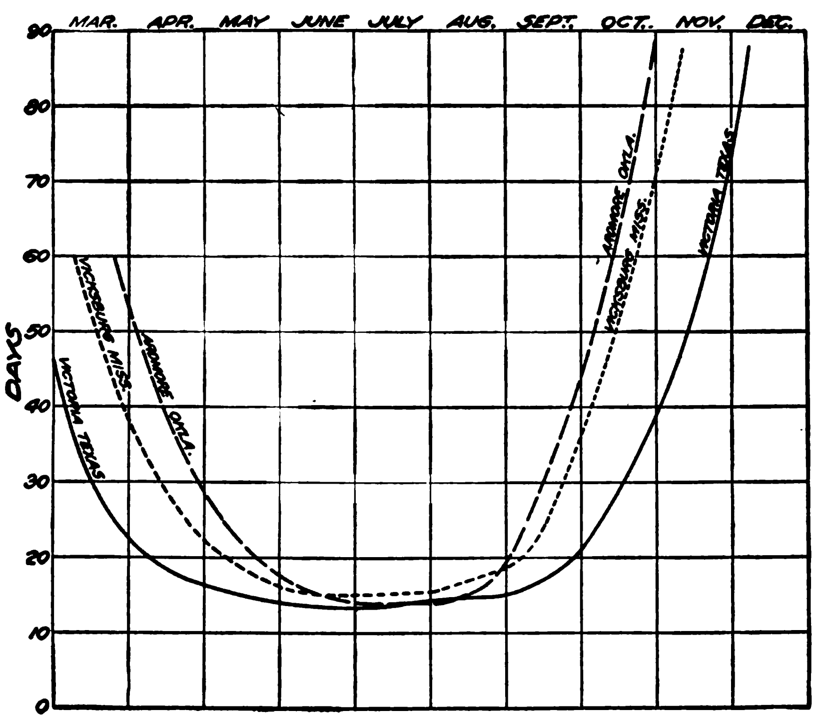



FIG. 13.—Diagram illustrating normal developmental period of boll weevil in squares, by months, at Victoria, Tex., Ardmore, Okla., and Vicksburg, Miss. (Original.)

Pensacola, Fla., would show almost as wide a curve, but there the weevil would show less rapid development in the hottest months. The Memphis, Tenn., curve is slightly wider than that for Ardmore, Okla., and Dallas corresponds almost exactly with Vicksburg. It is

interesting to note that Ardmore shows only four and one-half months in which the developmental period can be under 30 days. Adding the preoviposition period to the developmental period, it is evident that unless the weevil adapts itself to the northern conditions latitudes north of Ardmore can have only a fraction over three generations in a year, whereas Victoria, with seven months in which the developmental period is less than 30 days, frequently has six generations.

### VARIATIONS OF DEVELOPMENT IN BOLLS.

It is of interest to note the variation in development in bolls due to the length of time the boll hangs on the plant. At Victoria, Tex., in June the development was 15 days for a boll hanging 1 day and 39 days for a boll hanging 26 days, while in bolls which did not drop, it frequently took over 60 days, with 67 as the maximum. The average developmental period of 67 weevils at Victoria and Dallas was 41 days, or more than twice the average period of weevils in squares. This difference may be considered as due to a combination of the factors of lower temperature, greater humidity, and less nutritious food.

### MISCELLANEOUS VARIATIONS.

There are also some variations in development which can not be attributed to any of the causes cited above. Undoubtedly the insect adapts itself to the supply and condition of the food available. Consequently, under the same climatic conditions weevils in very small or delayed squares develop more quickly than those where the food is more suitable. Such variations are illustrated by Table XXVIII, which relates to the developmental periods of weevils of the third generation at Alexandria, La., in 1907.

TABLE XXVIII.—*Table showing variations in the developmental period of boll weevils in the third generation at Alexandria, La., in 1907.*

| Date of oviposition. | Number of stages. | Total egg days. | Average egg period. | Total larva days. | Average larval period. | Total pupa days. | Average pupal period. | Total weevil days. | Average total period. |
|---|---|---|---|---|---|---|---|---|---|
| September 2 | 1 | 1 | 1 | | | | | | |
| Do | 4 | 4 | 1 | 24 | 6 | | | | |
| Do | 7 | 7 | 1 | 42 | 6 | 28 | 4 | 77 | 11 |
| Do | 4 | 4 | 1 | 28 | 7 | | | | |
| Do | 7 | 7 | 1 | 49 | 7 | 28 | 4 | 84 | 12 |
| September 1–4 | 54 | 108 | 2 | | | | | | |
| September 1 | 1 | 2 | 2 | 7 | 7 | 3 | 3 | 12 | 12 |
| September 4 | 3 | 3 | 1 | 24 | 8 | 12 | 4 | 39 | 13 |
| September 5 | 2 | 4 | 2 | | | | | 26 | 13 |
| September 3 | 2 | 4 | 2 | 10 | 5 | 12 | 6 | 26 | 13 |
| September 4–5 | 10 | 20 | 2 | 60 | 6 | 50 | 5 | 130 | 13 |
| September 1–5 | 30 | 60 | 2 | 210 | 7 | 120 | 4 | 390 | 13 |
| September 2 | 5 | 5 | 1 | 20 | 4 | 45 | 9 | 70 | 14 |
| Do | 16 | 16 | 1 | 112 | 7 | 96 | 6 | 224 | 14 |
| Do | 4 | 4 | 1 | 40 | 10 | 16 | 4 | 56 | 14 |
| Do | 12 | 24 | 2 | 72 | 6 | 72 | 6 | 168 | 14 |
| September 3–4 | 3 | 6 | 2 | 21 | 7 | 15 | 5 | 42 | 14 |
| September 2–4 | 18 | 36 | 2 | 144 | 8 | 72 | 4 | 258 | 14 |
| September 2 | 9 | 18 | 2 | 81 | 9 | 27 | 3 | 126 | 14 |
| August 31 | 14 | 42 | 3 | | | | | | |
| Do | 3 | 9 | 3 | | | | | 42 | 14 |
| Do | 3 | 9 | 3 | 24 | 8 | 24 | 8 | 42 | 14 |
| September 1 | 2 | 4 | 2 | 14 | 7 | 12 | 6 | 30 | 15 |
| August 31 | 4 | 12 | 3 | 32 | 8 | 16 | 4 | 60 | 15 |
| September 1 | 6 | 12 | 2 | 42 | 7 | 42 | 7 | 98 | 16 |
| August 31 | 2 | 6 | 3 | 16 | 8 | 10 | 5 | 32 | 16 |
| Do | 3 | 9 | 3 | 24 | 8 | 18 | 6 | 51 | 17 |
| August 26 | 3 | | | | | | | 57 | 19 |
| Do | 3 | | | | | | | 60 | 20 |

TABLE XXVIII.—*Table showing variations in the developmental period of boll weevils in the third generation at Alexandria, La., in 1907*—Continued.

TOTALS AND AVERAGES.

| Date of oviposition. | Number of stages. | Total egg days. | Average egg period. | Total larva days. | Average larvel period. | Total pupa days. | Average pupal period. | Total weevil days. | Average total period. |
|---|---|---|---|---|---|---|---|---|---|
| Egg period | 229 | 436 | 1.9 | | | | | | |
| Larval period | 149 | | | 1,096 | 7.3 | | | | |
| Pupal period | 141 | | | | | 717 | 5.0 | | |
| Total period | 152 | | | | | | | 2,198 | 14.4 |

DEVELOPMENT OF WEEVILS IN THE SQUARES WHICH NEVER FALL.

It is generally true that squares seriously injured by the weevil sooner or later fall to the ground. The form of the absciss-layer grown when the square is injured determines whether it is to fall or to hang. (See Pl. XV.) This will be explained fully in connection with the discussion of parasites (pp. 143, 144).

Certain climatic and cultural conditions seem to increase the tendency of the cotton plants to retain the infested squares, although this tendency seems to be very largely of a varietal character. In the hanging position the square dries thoroughly and becomes of a dark-brown color. Although exposed to complete drying and the direct rays of the sun, the larvæ within are not destroyed by the sun in the same proportion as those which are exposed to the sun on the hot soil. However, control by parasites is much greater in the hanging squares than in the fallen squares—so much greater at times that the total mortality from all causes in hanging squares surpasses that of fallen squares. This matter will be dealt with more fully in a later section.

Owing to the much smaller number of squares which hang on the plants, we have been unable to obtain a sufficiently large series of records upon the development of the weevil in this class of squares, but the records available show that the development is slightly shorter in hanging squares than in the average fallen squares.

DEVELOPMENT DURING WINTER.

As is normal with many species of weevils, there is some development during the winter months. This development, however, is frequently cut short by severe freezes. In southern Texas larvæ and pupæ of the boll weevil which are in squares when frost comes are not always killed thereby, but slowly finish their development if the weather is warm enough for any activity, and the adults thus developed may live through the winter without feeding. Mr. J. D. Mitchell took a number of live larvæ, pupæ, and adults from bolls in a field at Victoria, Tex., on December 26, 1903, after two hard frosts and one freeze. Two weeks later, from a field in the same locality, after three hard frosts and two freezes (30° F.), he took another lot of live specimens in these three stages. On February 7, 1904, Mr. Mitchell took 32 adults, 1 pupa, and 4 larvæ, all alive, from standing stalks, and on February 14 he found 32 adults, 2 pupæ, and no larvæ. The material collected at different times up to February 14

included 197 specimens, 23 larvæ, 30 pupæ, and 144 adults. It is therefore evident that large numbers of weevils go into the winter in the immature stages, and there is every probability that, in the southern part of Texas at least, many of them live and mature, emerging in the spring. It may be that this gradual maturity of the hibernated weevils is one of the reasons why they emerge so irregularly from their winter quarters.

Prof. Sanderson, in Bulletin 63 of the Bureau of Entomology, mentions that in March, 1903, Mr. W. P. Allgood sent him from Devine, Medina County, Tex., a quantity of bolls, which were examined March 12. Twenty per cent of the bolls contained weevils, alive or dead, in some stage. In 40 bolls there were 40 live and 11 dead pupæ, 30 live and 40 dead adults, and 5 dead larvæ. Many of the adults had just transformed from pupæ. One live larva was found in the material. Estimating the survival of weevils in the plants in this field, Prof. Sanderson calculated that there would be about 10,500 weevils per acre in the spring. The lowest temperature which the weevils experienced in the locality from which these bolls were sent was 23° F. in February.

## SEASONAL ABUNDANCE.

### BROODS OR GENERATIONS.[1]

The term "brood" can hardly be applied in its usual sense to the generations of the weevil, as was pointed out by Dr. L. O. Howard in the first circulars of the bureau dealing with the problem. For several reasons no line of distinction can be drawn between the generations in the field at any season of the year, not even between hibernated weevils and the adults of the first generation. As has been shown, the period of oviposition among hibernated females is in some cases fully 3 months, while it averages 48 days. The average period of the full life cycle for the first generation is 25 days, and as the time for the second generation would be slightly less, it is evident that the first eggs for the third generation may be deposited at the same time as those for the middle of the second generation, and also with the very last of the eggs deposited by hibernated females for the first generation, as shown in figure 14. The great overlapping of generations thus produced prohibits the application of any of the common methods of ascertaining their limits. The complexity indicated for the first three generations becomes still further increased as the season advances, so that in October, for example, a weevil taken in the field might possibly belong to any one of five or six generations. Duration of life and the period of reproductive activity are important factors in determining the average number of generations. Periods of greatest abundance can not be regarded as giving any reliable information upon this point, since the number of weevils developed soon comes to depend largely upon the supply of squares.

In the case of the boll weevil, therefore, the information upon the number of generations must be drawn mainly from laboratory sources, but the results are supported by observations made in the field. Many of the hibernated weevils continue to deposit eggs until the middle of July, and some are active for fully a month longer. In 1903 the last eggs from hibernated weevils were deposited on August 27. In the course of rearing experiments made in 1902 it was found that many

[1] The following two paragraphs are taken from Bull. 51, Bureau of Entomology, pp. 95, 96.

weevils which had become adult about the 1st of August would continue to deposit eggs until the latter part of November. Considering the longest-lived weevils and their last-laid eggs, therefore, it is easily possible for two generations to span the entire year. The weevils developing after the middle of November may go into hibernation, and from their last deposited eggs produce weevils whose last offspring will be ready for successful hibernation again. This conclusion is based upon actual demonstration.

The maximum number of generations will be found by taking the first instead of the last eggs deposited in each case. In order to ascertain the maximum number of generations which would be possible, the figures for the development at Victoria, Tex., have been taken. Figure 14 is a diagram which shows the maximum number of generations possible and also the minimum number possible. This is based upon the mean temperatures of the various months at Victoria and the known period of development at such mean temperatures. The maximum number of generations of course begins with the first egg laid by the first weevil to begin oviposition in the spring and continues with the first egg of the first developing weevil from each generation. In this manner it will be seen that 10 generations are possible for weevils reared on squares. The last egg laid by the first emerged weevil and the last eggs laid by the following generations allow only three generations from the first emerged weevils, which might be considered the minimum. The maximum number of generations from the last emerging weevils by the same system can only be eight generations, whereas the minimum number of generations from the last emerged weevils will be two generations.

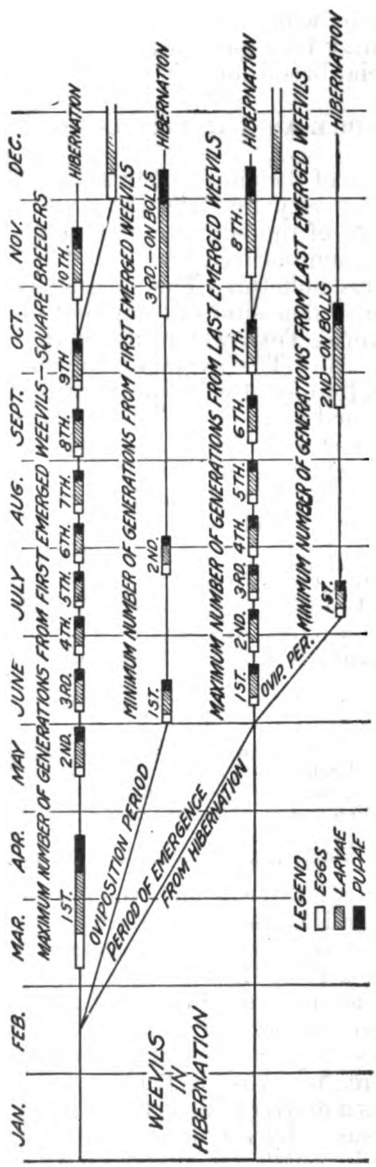



FIG. 14.—Diagram illustrating seasonal history of the boll weevil at Victoria, Tex. (Original.)

There is no basis for the idea that there is a distinct hibernation brood. The activity of the adults and the development of the immature stages is gradually retarded by the decline in temperature until

hibernation time arrives. Most of the weevils of the first two or three generations have probably died, or then do so, while most of the adults of later generations, still having considerable vitality, go into hibernation. It is certain that every generation may have some direct part in the production of weevils which are to hibernate. All weevils which are still strong and healthy when cold weather comes on may be expected to go into hibernation, so that there can be no special brood for this purpose.

## POSSIBLE ANNUAL PROGENY OF ONE PAIR OF HIBERNATED WEEVILS.

One of the most important factors in the development of an insect is its capacity for very rapid production. The conclusions as to the ability of the boll weevil in this respect are drawn from the following data, summarized from what has been set forth in preceding pages of this bulletin. The starting point is considered to be the average date of deposition of one-half of the eggs for the first generation at Victoria, Tex., which, under the usual conditions, seems to be about June 10. The average number of eggs deposited by a female was found to be 139. For the purpose of this computation 70 is the assumed number. The difference may be considered as an allowance for mortality or failure to hatch. The average period of development for each generation is 19 days. The average period between emergence of the adult and deposition of the first eggs is 6 days. The average period for the deposition of one-half the eggs for each generation is 18 days, thus making the average period for each generation 43 days. The sexes are produced in approximately equal numbers. For the sake of conservatism allowance has been made for only four generations in a season. The following table shows the rate of multiplication and the corresponding dates:

*Annual progeny of one pair of hibernated weevils.*

| | Weevils. |
|---|---|
| First generation, average adult June 29, numbering | 70 |
| Second generation, average adult Aug. 10, numbering | 2,450 |
| Third generation, average adult Sept. 22, numbering | 85,750 |
| Fourth generation, average adult Nov. 4, numbering | 3,001,250 |
| Total | 3,089,520 |

As a matter of fact, the multiplication during the early part of the season is so much more rapid that it is very certain that a large part of the third generation becomes adult by the middle of August. Possibly a more definite idea of the significance of this ability for reproduction may be obtained if we consider that, at the conservative rate given, the progeny from one fertile hibernated female might, in the course of four generations, number one weevil for every square foot of area in a 75-acre field.

As a matter of fact, the possibility of the multiplication is controlled primarily by the abundance of food supply. The maximum infestation is usually reached some time in August. If we assume that there are 6,000 plants on each acre of ground, and that each plant produces 100 squares for weevil attack up to August 1, we would find that if the usual percentage of these squares produces weevils, the actual

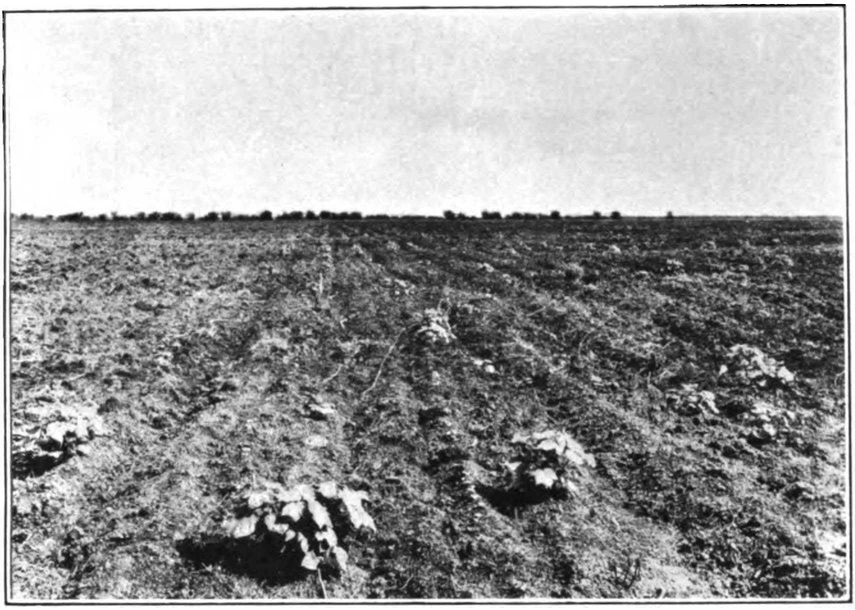


*Fig. a.*—Newly planted cotton field, with sprouts from overwintered cotton roots. (Original.)

*Fig. b.*—Fallen infested squares. (Original.)

FIELD CONDITIONS IN TERRITORY OCCUPIED BY THE BOLL WEEVIL.

multiplication would be limited to about 250,000 weevils per acre. It has been shown in this bulletin that on the average over 50 per cent of the weevil stages are destroyed by natural conditions. This means that the theoretical possibilities are never reached. In fact, it is doubtful whether the actual increase from a single pair exceeds 2,000,000.

Prof. Sanderson, in Bulletin 63, of this bureau, estimated that the actual increase in the number of weevils from the 1st of June to the 1st of September is about 50 times and certainly not over 65 times, where theoretically it would be 625 times.

### PROGRESS OF INFESTATION IN FIELDS.

It is of considerable importance to understand the rate of increase of the infestation in the fields. Normally, in a given cotton field the infestation when the squares have just begun to form is under 10 per cent, but this percentage increases very rapidly in proportion as the hibernation was successful. The infestation generally starts in a given field in the vicinity of timber or of buildings where cotton or cottonseed was stored during the winter. It then progresses in increasing circles until the entire field is scatteringly infested. From then on the increase is general until it is almost impossible to find an uninfested square. Table XXIX may be used to illustrate the progress of infestation in a given field.

TABLE XXIX.—*Progress of infestation by the boll weevil, field 1, Victoria, Tex.*[1]

| Block. | Date. | Number of squares examined. | Number of squares infested. | Percentage. | Remarks. |
|---|---|---|---|---|---|
| | 1903. | | | | |
| I | June 8, 9 | 4,200 | 675 | 16.0 | Work of hibernated weevils only. |
| I | July 13 | 467 | 211 | 45.0 | Second generation at work. |
| I | July 22 | 249 | 193 | 77.5 | Third generation beginning. |
| I | August 4 | 278 | 224 | 80.6 | |
| I | August 29 | 91 | 85 | 93.5 | About four generations now working. |
| II | July 30 | 358 | 168 | 46.6 | Much cotton dying from root rot. |
| II | August 1 | 331 | 148 | 44.7 | |
| II | August 4 | 300 | 100 | 33.3 | |
| II | August 20 | 699 | 636 | 91.1 | |
| | Total | 6,973 | 2,440 | 35.0 | |

[1] From Bull. 51, Bureau of Entomology, p. 114.

Additional illustrations are furnished in Table XXX.

TABLE XXX.—*Observations upon infestation by the boll weevil, various localities, 1904.*[1]

| Locality (Texas). | Number of plots under examination. | Number of examinations made. | Period covered. | Total squares examined. | Average percentage of squares showing weevil attack. | Total number of weevils taken with squares. | Average percentage of squares containing weevils. | Total number of small bolls examined. | Average percentage of small bolls attacked by weevils. | Average percentage of squares showing attacks by other insects. | Average percentage of clean squares. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1904. | | | | | | | | |
| Calvert | 12 | 2 | Aug. 23 to Sept 9. | 2,754 | 94.0 | 251 | 9.1 | 1,175 | 94.7 | 1.8 | 4.2 |
| Corsicana: | | | | | | | | | | | |
| A | 12 | 5 | July 29 to Sept. 12. | 6,951 | 72.4 | 376 | 5.7 | 2,506 | 71.9 | .6 | 27.0 |
| B | 11 | 5 | July 28 to Sept. 12. | 4,534 | 80.4 | 407 | 9.0 | 3,261 | 64.9 | .6 | 19.0 |
| Mexia | 15 | 5 | July 30 to Sept. 13. | 6,445 | 64.4 | 317 | 5.0 | 4,618 | 64.9 | 1.2 | 34.5 |
| Palestine | 22 | 2 | Aug. 26 to Sept. 14. | 3,719 | 91.3 | 274 | 7.4 | 2,456 | 92.8 | .7 | 8.2 |
| Victoria | 11 | 18 | June 18 to Sept. 24. | 13,227 | 54.2 | 170 | 1.3 | 544 | 66.9 | 6.1 | 44.6 |
| Wharton | 4 | 4 | July 22 to Aug. 25. | 5,005 | 65.0 | 167 | 3.3 | 230 | 46.4 | 10.2 | 25.3 |
| Total | 87 | ...... | June 18 to Sept. 24. | 42,635 | ...... | 1,962 | ...... | 14,790 | ...... | ...... | ...... |
| Average | ...... | 6 | ........... | ........ | 70.1 | ...... | 4.6 | ........ | 80.0 | 2.2 | 27.7 |

[1] From Bull. 51, Bureau of Entomology, p. 116.

Prof. Sanderson[1] has estimated that usually 50 per cent of the squares will be punctured by about two months after the cotton commences to square, at which time there would normally be about 100 squares to the stalk. When one-half of the squares are punctured it may be readily concluded that there are probably sufficient weevils present to prevent any more squares from forming fruit. It will be seen, therefore, that the critical period in the relation between natural increase of squares on the plant and increased injury by the boll weevil is during the period of six to eight weeks after the first squaring, which usually coincides more or less closely with the time between the appearance of the second and third broods of the weevils. Thus, if we consider six weeks as the average time for cotton to begin to square after planting, it will be seen that the bulk of the fruit must be set in 85 or 95 days after planting. In other words, to escape injury by the boll weevil, cotton must be so grown that the bolls will commence to open in about 100 days after planting and that all the fruit which will probably be secured must be set within 45 days after the squares begin to form. The advantage of early planted cotton and rapid-maturing varieties becomes, therefore, very apparent.

Field examinations have shown that the period of maximum infestation is reached between August 1 and 20, and that from 6,000 to 10,000 adult weevils per acre is sufficient to cause maximum infestation within a few days. The highest number of weevils per acre which has ever actually been recorded from a locality during the summer was

[1] Bull. 63, Bureau of Entomology, p. 38.

24,347 adult weevils at Port Gibson, Miss., in August, 1911.[1] With this number of weevils there was a record of only 37.03 per cent infestation of the remaining squares and bolls. Higher percentages of infestation have been recorded with much smaller numbers of adult weevils per acre.

### EFFECT OF MAXIMUM INFESTATION UPOM WEEVIL MULTIPLICATION.

At the time of maximum infestation the majority of the third-generation weevils are becoming adult and many of the hibernated weevils have died. About this time also a decrease in square pro-

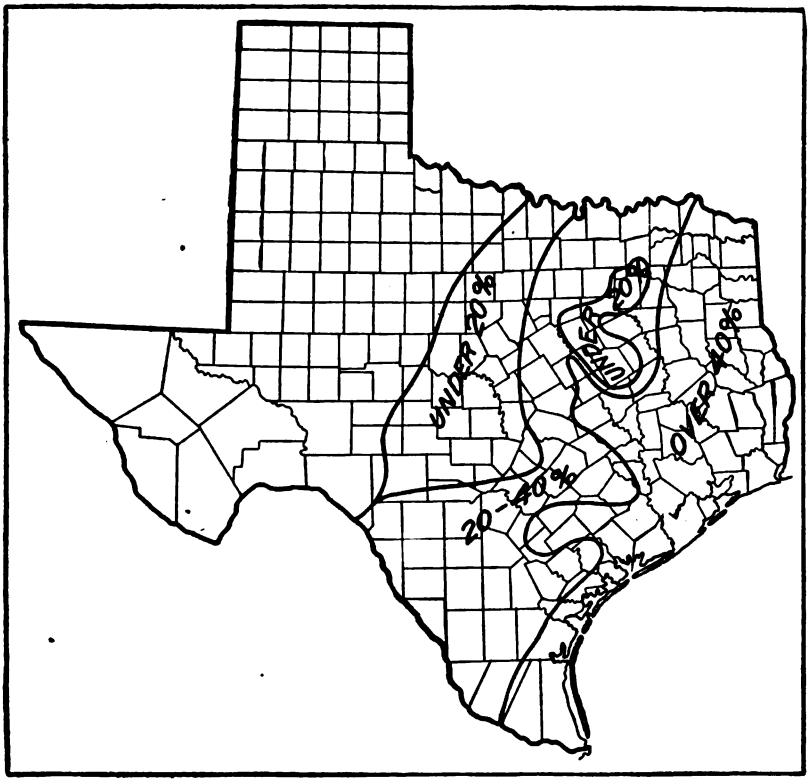



FIG. 15.—Status of the boll weevil in Texas in August, 1906; percentage of infestation of all forms. (Original.)

duction accompanies the maturity of the bulk of the crop, owing to the fact that the assimilative power of the plant is largely consumed in maturing seed. If dry weather occurs at this period, which is frequently the case in Texas, there is a further decrease in the number of weevils present. Not only are there fewer squares to become infested, but each square is also subjected to greater injury, and many which would otherwise produce weevils are unfitted as food for the larvæ by the decay which follows the numerous punctures. Several eggs may be deposited in each square, but as a rule only one weevil

[1] During the late fall the number may be much larger. See p. 76.

will develop. These general conditions frequently bring about a reduction of the number of weevils present in the field. This becomes evident to the planter by the number of blooms seen. Of course, the conditions soon change and the weevils become more abundant than before.

## STATUS EXAMINATIONS.

In order to become fully acquainted with the conditions of the weevil during the most important parts of the season, it has been the custom to conduct an extensive series of observations in the latter part of

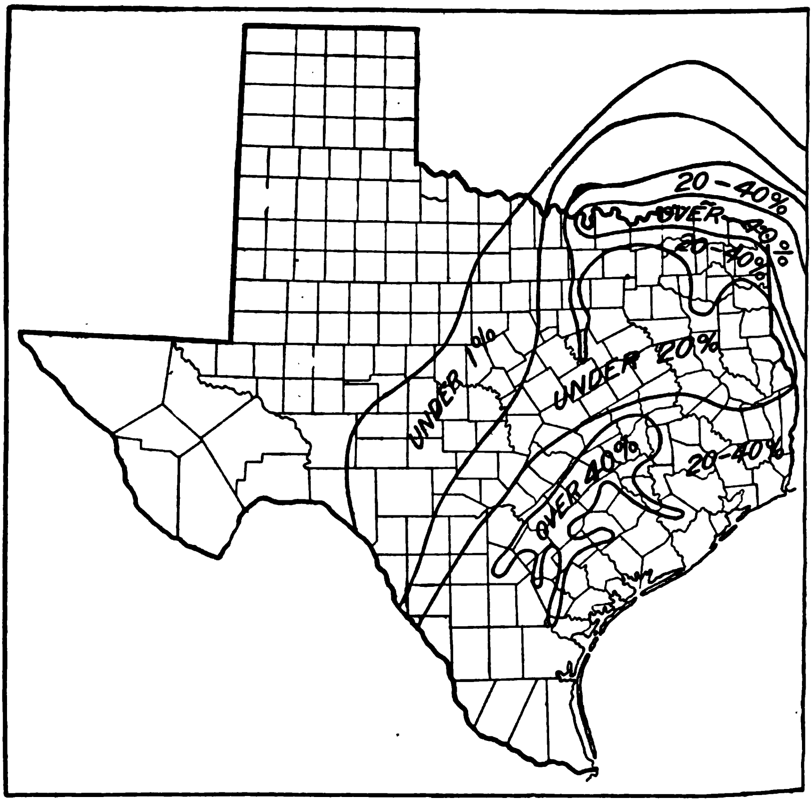



FIG. 16.—Status of the boll weevil in Texas in August, 1908; percentage of infestation of all forms. (Original.)

June and first part of July and again in the first half of August in order to learn the extent of damage being done by the weevil. These examinations have been made so thoroughly and have been distributed in such a manner that it has been possible, even in June, to determine the probable direction of the greatest movement of the weevil during the season, to point out the regions in which the damage to the crop will be greatest, and also to indicate where the control of the weevil during the winter has been of greatest consequence. The first "status" of the year frequently gives very definite evidence of natural control or an absence of it. While certain general methods of

control have been contrived, it is still true that some of the most important methods of control are those which are devised to suit particular emergencies. These have been indicated from time to time in connection with the status reports.

## RELATION OF WEEVILS TO TOP CROP.

After considerable cotton has been matured fall rains often stimulate the production of a large number of squares, and many planters are misled by the hope of gathering a large top crop from this growth.

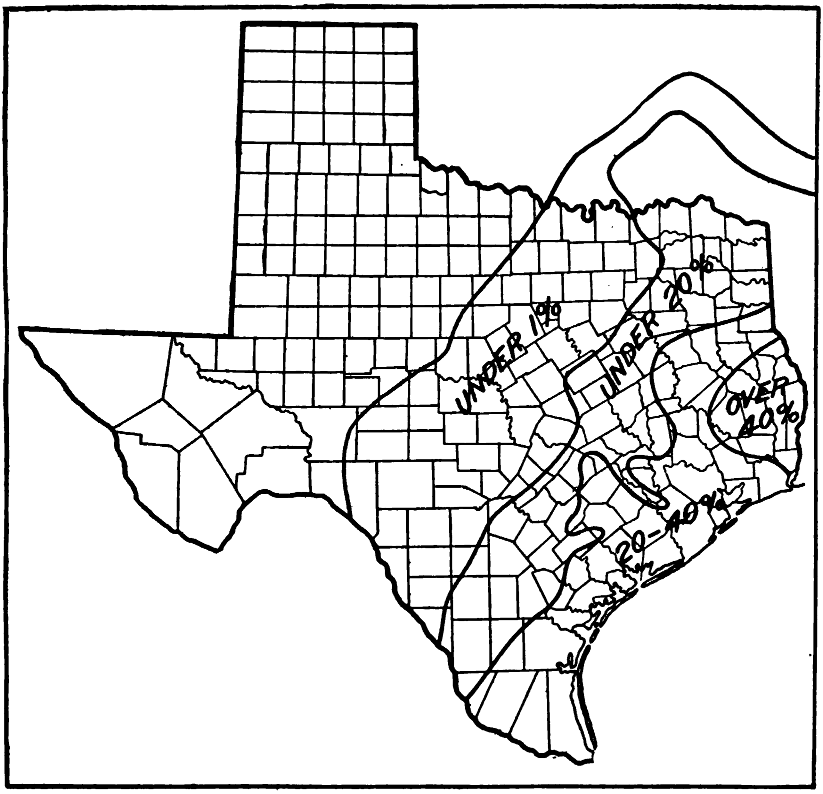



FIG. 17.—Status of the boll weevil in Texas in August, 1909; percentage of infestation of all forms. (Original.)

The joints of the plant are short, and the squares are formed rapidly and near together. Though weevils may have been exceedingly numerous in the fields, their numbers will have become so decreased by the dispersion and by the limited quantity of food that they can rarely keep up with the production of squares at this period of rapid growth. Many blooms may appear, and the hope of a large top crop increases. It has been a very rare occurrence that planters have gathered top crops, even in years of no injury from insects.

The chance of its development, though always small, becomes practically inconsiderable wherever the weevil is present in numbers.

In the senior author's experience of 10 years only one example of a top crop in a weevil district has been seen. This happened in the vicinity of Brownsville, Tex., in 1911. The production of a few bolls on the tops of the plants was due to a rare combination of exceptional influences, including very dry weather during the summer, defoliation at an early date by the cotton worm, and late rains after the weevils were greatly reduced in numbers.

Neither the very remote chance of gathering a top crop nor the actual injury which is being done to the crop of the succeeding year by allowing that growth to continue until frost kills it is generally

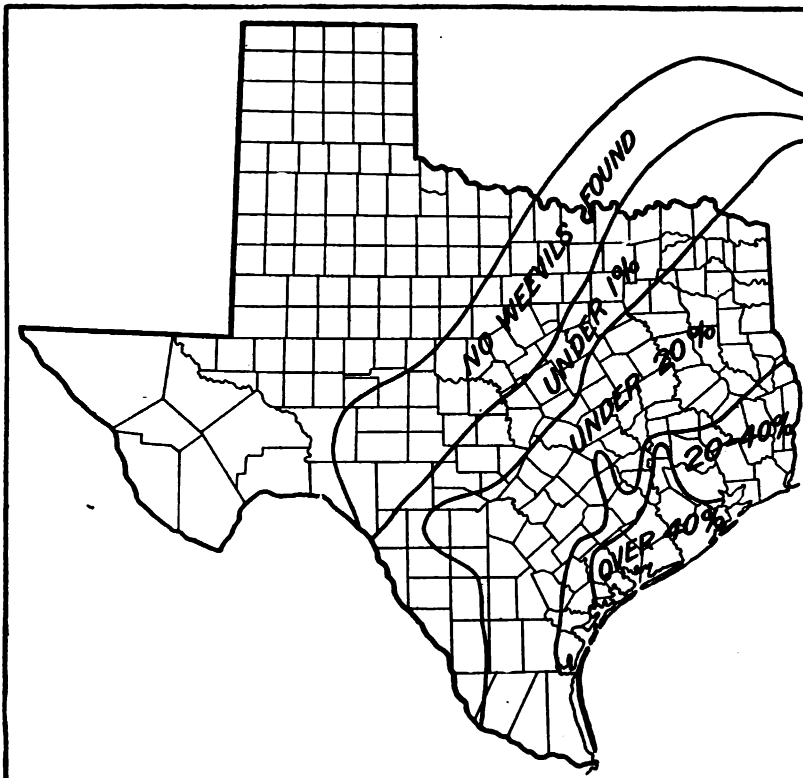



FIG. 18.—Status of the boll weevil in Texas in August, 1910; percentage of infestation of all forms. (Original.)

appreciated by planters. Because of the apparent abundance of squares and the presence of many blooms the plants are allowed to stand long after they might have been destroyed to the great benefit of the next crop. As is the case in the early spring, however, the abundance of squares increases greatly the production of weevils, and though a few bolls may set, they are almost certain to become infested before they reach maturity. Every condition, therefore, contributes to the production of an immense number of weevils very late in the season and at just the right time for successful hibernation. As a result, far greater injury is done to the crop of the following

season with no actual gain in the yield of the current season. Plants standing until frosts kill them are often allowed to remain throughout the remainder of the winter and easily furnish an abundance of favorable hibernating places for the weevils. The consequence of this practice is that so many weevils are carried through the winter alive that the yield of the next year is much less than it might have been but for the farmer's indulgence of the forlorn hope of a top crop. It is far wiser to abandon the uncertain prospects of a top crop and destroy the stalks in order to insure a better crop the following year.

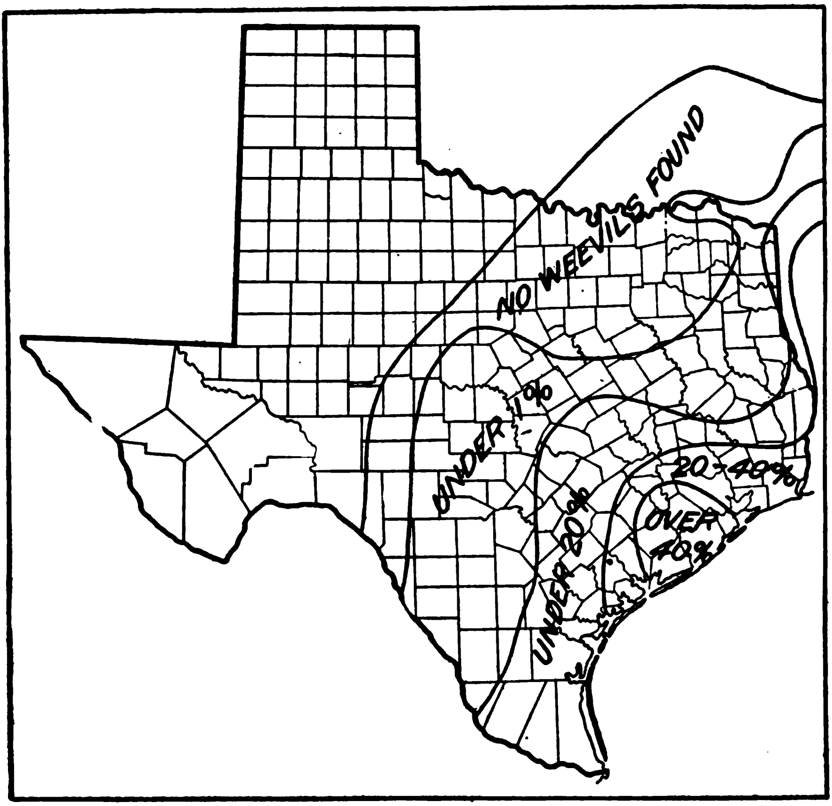



FIG. 19.—Status of the boll weevil in Texas in August, 1911; percentage of infestation of all forms. (Original.)

### VARIATIONS IN ABUNDANCE OF THE WEEVIL FROM YEAR TO YEAR.

The decrease in damage by the weevil in Texas in the last few years has led some observers to believe that the insect will finally disappear altogether. Investigation shows that this belief is erroneous. In 1897 the French entomologist, Dr. Paul Marchal, published a paper which set forth some of the essential factors governing insect abundance from year to year. This author called attention to the more or less regular periodicity in the abundance of certain well-known injurious insects. In this country the cotton leaf worm, *Alabama argillacea* Hübner, is an example of such periodical abundance. The

application of Dr. Marchal's law to the abundance of the boll weevil will be discussed in the following paragraphs.

When the boll weevil entered the United States, it was released from most of its natural enemies and was in the portion of the cotton belt most resembling its natural home. Naturally, it increased with great rapidity. In fact, the weevil was on what may be called the upward curve of numerical abundance from 1892 to 1896. In the meanwhile, native parasites began to adapt themselves to it, and we may assume that their abundance might be indicated by a curve parallel to but behind that of the boll weevil. In 1896 a severe drought was the cause of a very sudden decrease in the numbers of the weevil and of course also acted upon the parasites. Following 1896 the increase in abundance of the weevil was comparatively slow, owing to the unlimited opportunities for spread. The maximum point in this increase appears to have been reached in the autumn of 1904 and may have been partly due to the fact that in that year the abundance of the parasites was on the decrease. In the winter of 1904 a severe cold period turned the curve of abundance downward, but the decrease was slow until the fall of 1907, when another severe freeze caused a sudden falling off. Floods in the spring of 1908, drought in the summer, a freeze in the fall of the same year, and droughts in the summers of 1909, 1910, and 1911, followed in 1909 and 1910 by severe winters, all combined to reduce the weevil still more. On the other hand, from 1904 to 1908 the influence of the parasites was increasing and from then until 1911 decreasing. As Dr. Marchal pointed out, it is very rare that some condition does not intervene just before the number present has reached zero and save the species from extermination. The weevil will undoubtedly frequently be greatly reduced in large regions, but in such areas the inflow from other localities will serve to bring about early reestablishment. (See fig. 20.)

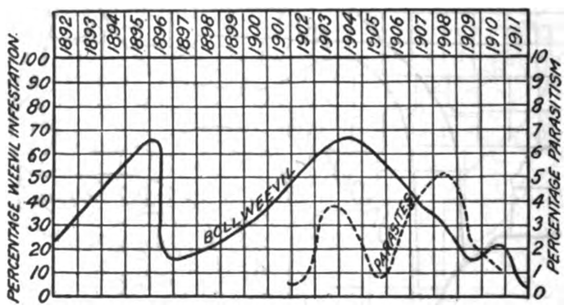



FIG. 20.—Curves of numerical strength of the boll weevil and its parasites. The boll weevil curve is at the scale of 2 to 10 and represents the percentage of infestation in August in Texas. The parasite curve is at the scale of 1 to 1 and represents the percentage of mortality of the boll weevil due to parasitism. (Original.)

Undoubtedly the adverse seasons of recent years will be followed by others which will allow the weevil to reach approximately its former abundance. This alternation of years of scarcity and of abundance will continue indefinitely. Naturally, no definite prediction can be made as to the number of years which will be included in the alternating periods.

The series of Texas maps presented herewith (figs. 15–19) illustrates the variations in the percentage of infestation in August during a series of years in which the weevil abundance was at a low ebb. They also show very plainly how the areas of heavy damage are shifted by more or less local causes.

The status examinations upon which these maps were based show the following average percentages of infestation in Texas. (See Table XXXI.)

TABLE XXXI.—*Percentage of infestation by the boll weevil in Texas in August; years 1906 to 1911.*

| Year. | Percentage of infestation. |
|---|---|
| 1906 | 50.11 |
| 1907 | 38.09 |
| 1908 | 32.32 |
| 1909 | 14.78 |
| 1910 | 20.79 |
| 1911 | 1.12 |

## NATURAL DISSEMINATION.

The natural movements of the boll weevil are of several more or less distinct kinds. For several months in the spring there is a general dispersal in search of food. After the cotton commences to square there is a steady spread across the fields from the vicinity of the places where the insects have hibernated. This may become a spread from field to field. In late summer there is a sudden and wide dispersal, which is shortly followed by a search for hibernation.

### SPRING SEARCH FOR COTTON.

After a quiescent period of from five to eight months the weevils leave their hibernation quarters and start in search for food. During a warm period, such as was experienced in March, 1907, many weevils come out of hibernation long before any cotton has made its appearance. Without doubt these weevils wander considerable distances and finally either die or reenter the quiescent state on account of lower temperatures. As the emergence from hibernation covers a period of about three months there is little or no regulation of the direction of flight, such as might occur if all emerged at the same time during a high wind. Elaborate tests have been made by releasing marked weevils fresh from hibernation in the vicinity of cotton fields. Invariably after careful search a very small percentage of these weevils have been found in the nearest cotton.

The experiments of Mr. A. C. Morgan in 1906 at Victoria, Tex., give the most specific data on individual flight. Seven hundred and eleven weevils were used in the experiments, of which 355 had been fed and 356 were unfed. Of the fed weevils 179 were male and 176 female, while of the unfed weevils 183 were male and 173 female. This gave a total of 362 male and 349 female weevils. The maximum flight by a fed male was 775 yards, by a fed female 350 yards, by an unfed male 225 yards, and by an unfed female 500 yards. The experiments also showed the average distance per 24 hours for a fed weevil as 63.3 yards, and for an unfed weevil, 66.6 yards. It was generally observed that the weevils flew with the prevailing wind.

Observations on the early spring movement of the weevil in Mississippi in 1910 showed the utility of the rotation of crops. During

the two status examinations made in 1910 in southern Mississippi it was very evident that in these fields in which cotton followed corn there was a conspicuous absence of infestation until the fall dispersion of 1910, whereas in neighboring fields in which cotton followed cotton the infestation was in some cases extremely high, even in June.

These circumstances and many others which have been observed in the spring indicate a rather irregular dispersal from the places of hibernation which may carry the weevils considerable distances in all directions. On the extreme border of the infested territory this may result in the infestation of entirely new territory.

## SPRING SPREAD WITHIN THE FIELD.

The spread from plant to plant begins in the portions of the field adjacent to favorable hibernation quarters. It has usually been found that the early summer infestation begins at a point adjacent to timber or near farm buildings where seed or seed cotton has been stored. From these centers it is generally easy to trace the infestation to other parts of the field. The movement of the weevils from these centers, however, is not regular. They occasionally fly to rather distant portions of the field and then start new centers, but on the whole the progress is steady and soon brings about a complete infestation of the field.

A number of observations were made to determine the degree of movement of hibernated weevils in a field at Victoria, Tex., in 1904. The weevils were marked so that they could be recognized, and frequent examinations were made to determine the location of each specimen from day to day.[1] It was found that the maximum time one weevil remained upon a single plant was 18 or more days, the observations having been discontinued after the eighteenth day. The average time positively found in 73 cases was 4 days, with a possibility for this same number of observations of 6⅔ days. Probably a true average lies approximately between these results, and, if so, we may assume that about 5⅓ days usually intervene between the movements of each weevil. In the whole series of observations, extending over 25 days, for weevils which were found after being liberated, only 57 movements were recorded. The total of these movements averaged only 62 feet each in 177 movement days. This would give us an average movement of but 0.35 foot per day for each weevil in a field where stubble plants were quite abundant, where squares were forming upon fully one-third of the plants, and during a period for which the mean average temperature was 78.6° F.

## SUMMER FLIGHTS.

During the summer there is more or less general movement within the cotton fields and also from field to field. These flights are at first weak, but gradually become more pronounced and finally lead into the great dispersal of the late summer and fall.

During the summer the conditions on the border of the infested area are peculiar. Many of the weevils which arrived late in the fall of the preceding year are unable to survive the winter on account of

[1] The remainder of this paragraph is from Bulletin 51, Bureau of Entomology, p. 112.

their exhausted condition. Therefore, the line of continuous infestation may be considerably behind the line of continuous infestation resulting from the last movement of the preceding year. Outside of this continuous line is a strip of considerable width in which the weevil is found scatteringly. The summer flights cause these isolated infestations to coalesce.

### FALL DISPERSION.

All movement of the weevil at other seasons is insignificant in comparison with the great dispersion of the fall which carries the insect far into new territory. It is this movement which causes the more or less regular annual advance in the cotton belt. In one sense this dispersion is merely an overflow from territory in which the insects have become so numerous that there remain no opportunities for breeding. In another sense it appears to be the result of a strong instinct which the weevils possess to invade new regions. At any rate, they show great activity in the late summer and fall. The main causes of the fall flight, therefore, appear to be (1) a scarcity of food and breeding places due to maximum infestation, and (2) an instinct to invade new territory. Several conditions may tend to precipitate the movement or strengthen it. Among these are damage by other cotton insects, which hastens maximum infestation, and drought, which may have the same effect by preventing the continued fruiting of the plants.

There seems to be no special tendency to fly in any particular direction, although prevailing winds frequently cause the majority of the insects to follow one course. This has been observed to be southeast, north, and east in different localities. If not governed by the wind, any weevil which takes flight is as likely to fly toward the old infested territory as in any other direction. It is, therefore, only a portion of the dispersing weevils which enlarges the infested territory.

The distance any weevil will fly in this movement depends upon how soon it finds uninfested cotton. If on the first flight it finds only heavily infested cotton or none at all it will take wing again. In this way a succession of flights may carry the insect over a wide territory. In one case a distance of over 40 miles has been known to be covered in this manner. If, on the other hand, the first flight carries the weevil into an uninfested field it remains there. Consequently, the advance is slowest in regions where cotton fields are numerous. The occurrence of the leaf worm, *Alabama argillacea*, in great numbers in any locality destroys the food and tends to cause decidedly longer flights of the dispersing weevils.

So far as we have been able to discover, the weevil has no sense by which it can locate cotton. Such a sense may exist, but the general aimless flight of thousands upon thousands of individuals seems sufficient to account for the infestation of all fields in new territory. An interesting observation was made by the junior author and Mr. G. N. Wolcott near Meridian, Miss., that the early dispersing weevils, in flying through hill country with heavy woods, found only the patches on the tops of the hills and from these gradually spread downward to the denser cotton.

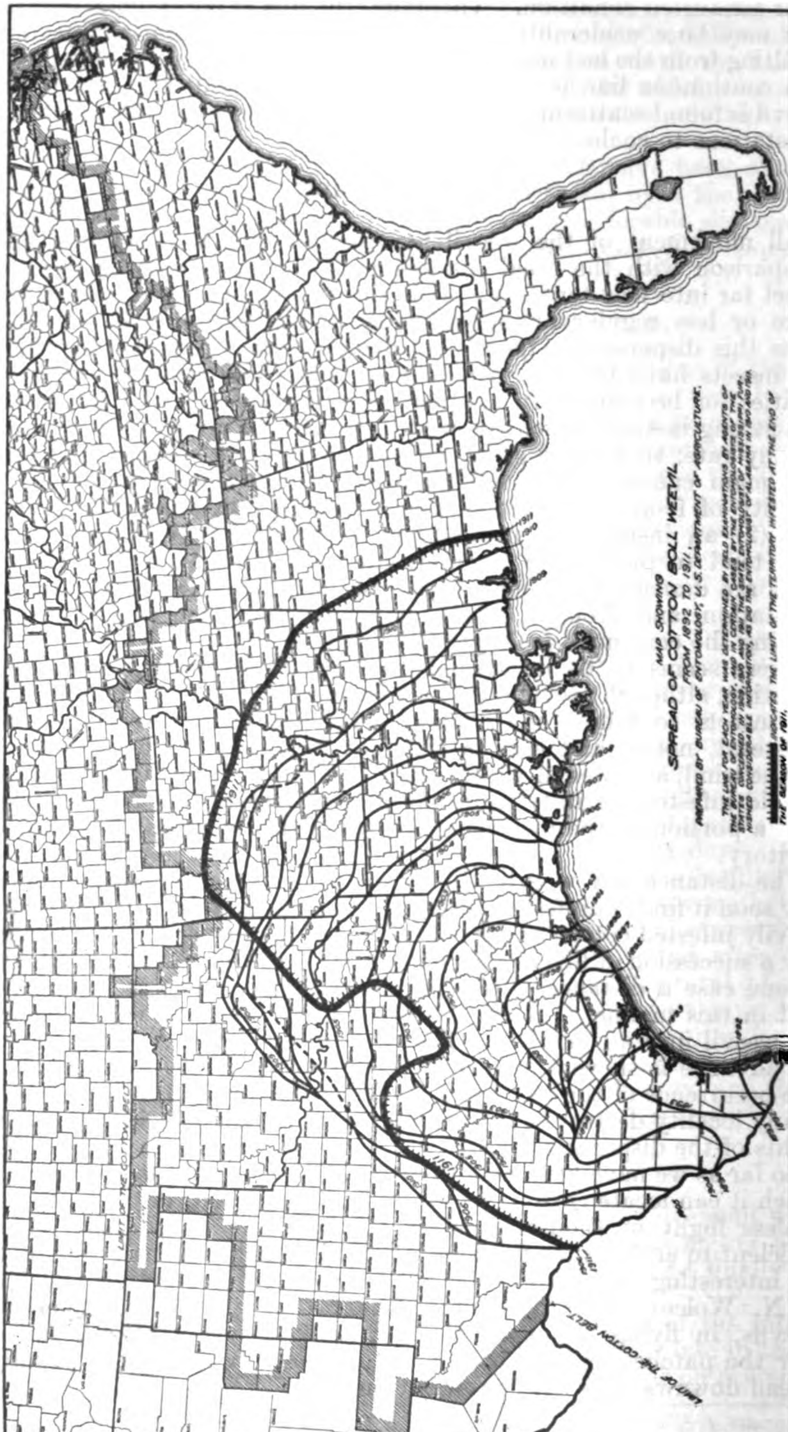



FIG. 21.—The spread of the cotton-boll weevil from 1892 to 1911. (From Hunter.)

The fall movement of the weevil has been studied carefully each year since 1904. (See fig. 21.) The circumstances have been different each season, but with uniformity within certain limits. Several examples will be given. In the fall dispersal of 1904 the weevils seemed to have crossed the line of continuous infestation in southern Louisiana about August 1, and a little later toward the north, but in all cases the movement had crossed the line by the 20th of August. In this year there were two very well-defined dispersals with about a month intervening. This might indicate that the first dispersal was caused by the lack of food and that in another month a new generation found itself confronted by the same conditions as its predecessor and was also forced to disperse.

In 1906 the movement seems to have been more irregular, for the first serious new infestation was in central Louisiana rather than in the southern part of the State. In the light of present knowledge this was probably due to the smaller amount of cotton grown in the pine woods of southern Louisiana, which naturally gave rise to comparatively few weevils for the flight. The year 1906 was the last in which any appreciable movement into western Texas was observed until 1910.

In 1907 and 1908 the eastward and northeastward progress of the weevil carried it far into regions where much cotton is produced. The year 1909 exhibited some very striking features. There had been a considerable loss in the infestation during the winter of 1908 in northern Louisiana and eastern Arkansas, a region of very extensive cultivation of cotton. During the autumn of 1909 the almost continuous movement in southern Mississippi from field to field in the rather sparsely cultivated areas amounted to 120 miles for the season. In the delta region of Louisiana, Mississippi, and Arkansas, where the weevils encountered a belt of extensive cotton culture from which they had been driven back during the previous winter and were stopped by the large amount of food available, they were unable to gain more than 20 miles of new territory.

In 1910 a peculiar situation developed. It was discovered that high winds had caused an extensive movement into central Mississippi in May or June. In the entire history of the weevil there had previously been known but one occasion when a severe storm caused a dispersal of the insect. A study of the records of the Weather Bureau brings out the fact that there was a series of cyclonic storms about May 7, 1910, passing northeastward across Mississippi from the heavily infested regions around Natchez. We have been unable to find any other explanation of such an extensive movement in the early spring. Studies conducted during the summer and fall of 1910 revealed the existence of many sporadic infestations throughout central Mississippi, probably due to the storm. From these isolated infestations the weevils spread in concentric circles until about the end of November, when the intervening territory became covered.

The winter of 1909–10 was unfavorable to the weevil in the Delta. When the dispersion season opened it was noticed that in strong contrast to the rapid movements in central Mississippi, the weevils in the Delta advanced slowly. During the entire season there were only two courses of considerable movement in the Delta region. One of these was along the Mississippi River through the fields adjoining the levees. The other extensive movement in the Delta country

was in a belt coincident with a strip known locally as the "dogwood ridge."

The winter of 1910–11 also was unfavorable to the weevil. It began with a sudden freeze on October 29, which extended over almost the entire infested region and destroyed the food supply. Severe cold weather in January also contributed to the control. Examinations made in June and August, 1911, demonstrated that the weevil was in the lowest average condition numerically that it had ever reached. It was completely exterminated in the northern portion of the Texas and Oklahoma black prairie, but west of this was a region which escaped the first frost, and where the weevils occurred in more or less normal numbers.

The defoliation by the leaf worm was so widespread that a condition of maximum infestation was reached with much smaller numbers of weevils than usual, and the scarcity of proper food supply forced a phenomenal advance along the Mississippi River toward Tennessee.

In Texas and Oklahoma there were some gains made in the lost territory, but even with these gains 24,000 square miles of territory were not reinfested. The northern limit of cotton production in western Arkansas was reached, and the line of infestation stopped only about 10 miles short of the southwestern corner of Tennessee. Great gains were made in northern Mississippi, and western Alabama and Florida became invaded for the first time.

## HIBERNATION FLIGHT.

The fall dispersion movement continues more or less regularly until frosts occur and mark the beginning of the hibernation period. Thus, in many cases the fall dispersion is a flight into winter quarters. However, a period of feeding seems to be necessary for successful hibernation. Therefore, few of the dispersing weevils which are forced into hibernation by cold weather survive. Those that do survive seem to be supplied from a distinct movement into hibernation quarters at the end of the season. The most striking observation on this point was made by Mr. J. D. Mitchell in the winter of 1906. Although there had been no lowering of the temperature, he found on entering the cotton fields on November 18 a very restless activity among the weevils. Adults were observed upon the squares with their wings open and flew at the least disturbance. He observed many hundreds of weevils rising into the air and disappearing. The weather was warm and pleasant, and there appeared no reason at the time for this flight, which continued for about two days. In a few days the temperature became decidedly lower, and Mr. Mitchell was able to find only a very few weevils remaining in the fields. This note is of special interest in connection with the observations on climatic control, which will be discussed later.

## OTHER FORMS OF NATURAL SPREAD.

Heavy windstorms, hurricanes, and cyclones are powerful agents in the spread of the weevil. It is believed that the great storm of September 8, 1900, in Texas, carried the infestation northward many miles. As has been stated, the storms of about May 7, 1910, in Mississippi, were instrumental in causing a considerable increase of the infested territory in that State.

There is another method of natural spread of some local importance. In hill lands, especially, rains sweep immense numbers of infested squares to the lower parts of the fields. Cotton squares are remarkably impervious to water, and weevils may develop in them after decay is far advanced. These squares may be carried many miles from their source and deposited under favorable conditions for the emergence of the weevils.

## ARTIFICIAL DISSEMINATION.

While the natural dispersion of the boll weevil is by far the most important means by which new territory becomes invaded, there are certain artificial means of dissemination which are of some importance. The more noteworthy of these are connected with the handling of the cottonseed and cottonseed products. Many weevils are carried to the gins with the cotton. From the gins dissemination may take place in several ways. The weevils may be carried back to the farms in cottonseed to be used for planting, or they may be shipped by rail to the oil mills along with the seed. Moreover, weevils are likely to secrete themselves during cool weather in the wrapping of cotton bales. In this manner transportation along with the lint is possible, although experience has shown that the danger from this source is inconsiderable. When the cottonseed arrives at the oil mill there is chance of infestation from flight into neighboring cotton fields. The greater damage, however, is in the shipment of weevils beyond the oil mills in the cars which have been used for the purpose of carrying the seed to those establishments.

Among the means of minor importance may be mentioned the incidental carriage by vehicles, including railroad coaches, by the movement of plantation laborers, and by intentional carriage for the purpose of experimentation or exhibition. The possibility of spread by these various means will be discussed in the following paragraphs:

### MOVEMENT OF SEED COTTON.

Many immature or teneral weevils are carried to the gins with the seed cotton. Adults are frequently found crawling over the wagons filled with unginned cotton. The devices for removing foreign matter from cotton in the process of ginning are numerous and effective. Many of the weevils are removed or destroyed, but adults, as well as larvæ and pupæ, are likely to pass through the gin with the seed. This has been determined by the Bureau of Entomology by running gins experimentally.[1] Many of the weevils, consequently, are carried into the seedhouse along with the cottonseed. Moreover, many of those that are removed by the cleaning devices are not injured. They pass along with the motes into a barrel or box, which is generally uncovered, and from there they frequently fly about and find their way into the cottonseed, or they may secrete themselves in the bagging of the bales standing in the gin yard. Furthermore, many of the adult weevils are not taken into the gin house at all. Being on the cotton in the wagon, they are disturbed by the process of unloading and may fly to any portion of the plant. Consequently, cottonseed in storage at the gin may become infested by any one of the

[1] For a full account of these experiments see Farmers' Bulletin 209.

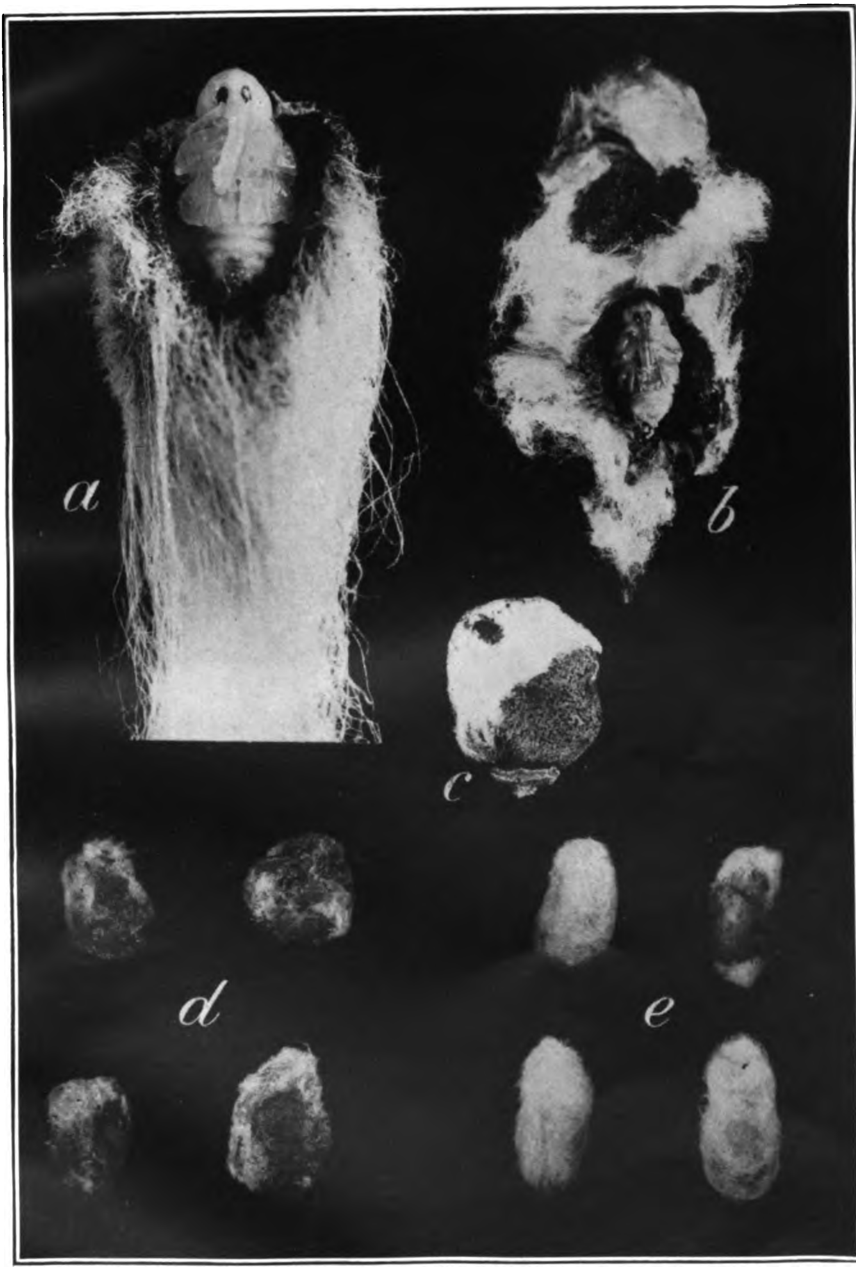
following means: (1) By passage of weevils through the gins along with the seed; (2) by the weevils finding their way into the seed house from the receptacle containing the discharge from the cleaner feeder; and (3) by flight from the wagons during the process of unloading. Thus, gins may serve as important agencies in the dissemination of the boll weevil by the shipment of the seed or possibly of baled cotton. That the danger in baled cotton is slight is shown by the fact that no colonies have been found to have become established in spite of extensive shipments out of the infested territory which have been made for several years.

In many localities the unginned cotton is carried for a distance of 20 miles or more to the gins. It frequently happens that this carriage is into uninfested territory. Under such conditions it is evident that an important form of artificial dissemination of the weevil occurs. Two examples will be given of the possibility of the dissemination of the weevil by such means. In October, 1904, a shipload of unginned cotton was carried across Lake Calcasieu, La., from Grand Lake and Lakeside to Cameron. The latter place was free of the weevil and isolated by extensive stretches of swamp lands. Shortly after the shipment reached Cameron, however, an infestation was found in the gin yard. It was in all probability due to the carriage of the cotton from the opposite side of the lake. In the other case a shipment of unginned cotton was made from Yucatan, Mexico, to Mobile, Ala., in 1909. The Mexican locality was infested by the boll weevil, while the region about Mobile was free of the insect. No infestation resulted in this case for the reason that the shipment from Mexico was accidentally delayed in transit and did not reach Mobile until all of the weevils had died. If the shipment had been made according to the regular schedule there is little doubt that an infestation in the vicinity of Mobile would have resulted.

## MOVEMENT OF COTTONSEED.

In ginning districts on the edge of the infested territory the customers are composed of those whose fields are infested and those whose fields are not infested. The inevitable result is that weevils are constantly brought into the gin yards by the farmers, and in the subsequent movements of the cotton are spread broadcast. Some of them may alight upon the wagons filled with the seed to be returned to the farm and consequently may be frequently carried to uninfested farms. The most striking illustration of infestation by this means was found in Shelby County, Tex., in 1904. An establishment on the border line ginned for farmers in a radius of 10 miles or more. Some of the customers had the weevil. The ginner himself had a few weevils on his place, but had raised an exceptionally large crop of big-boll cotton, for the seed of which quite a demand arose. An investigation of the farms in this district showed that all the customers who had purchased this seed had infestations near their seed house. Very few of the other farms in the vicinity were found to be infested.

Cottonseed is frequently shipped considerable distances from the gins to the oil mills. As has been shown there are abundant chances that the seed may become infested at a gin within the infested territory. (See Plate IX.) At the oil mills the cars are unloaded and




RELATION OF BOLL-WEEVIL CELLS TO SEED.

*a*, Boll-weevil pupa found in cotton seed; *b*, boll-weevil pupa in cell of lint from boll; *c*, weevil cell in dwarfed cotton boll containing live pupa taken among seed; *d*, weevil cells in bolls; *e*, cotton seeds. (Original.)

passed on to the railroads for other uses, frequently without being swept out at the mills. It is common in the lumber country for cars to pass from oil mills to lumber mills. Such cars are often found containing several pounds of seed in the corners. The lumber men sweep out this waste before loading their cars. In case cotton grows near the mill the danger is quite apparent.

An interesting example of the shipment of the weevil in cottonseed came to notice in Mexico a few years ago.[1] On January 5, 1903, it was discovered that Texas-grown cottonseed was being imported into the southeastern part of the Laguna district in Mexico.[2] Examination of this seed, made by Prof. L. de la Barreda, revealed the fact that six lots had been received from infested points in Texas and that each of these lots was at that time infested with live boll weevils. The results of an examination of samples from three consignments are given in Table XXXII.

TABLE XXXII.—*Result of examination of infested cottonseed shipped to Mexico.*

| Number of sacks of seed examined. | Boll weevils found. | Alive. | Dead. |
|---|---|---|---|
| 8 | 27 | 2 | 25 |
| 4 | 11 | 2 | 9 |
| 2 | 57 | 10 | 47 |
| 14 | 95 | 14 | 81 |

The results of these careful examinations show very clearly the possibility of transporting live weevils in shipments of cottonseed.

Unless the oil mill is within the infested territory and ships hulls to points outside there can be very little danger from this product. In fact, it is hardly possible that weevils are ever spread by means of cottonseed hulls.

## BALED COTTON.

One of the writers has found live weevils in bagging about bales consigned to Liverpool on the wharves at New Orleans. However, as has been pointed out, experience has shown that the danger from this source is very slight.

## PASSING VEHICLES.

Carriages, wagons, and railroad trains, in passing fields where the weevils are numerous, may carry them great distances, although few specific observations have been made on this matter.

## MOVEMENT OF FARM HANDS.

Many laborers frequently pass from infested territory to uninfested territory. Their practice is to use cottonseed for packing breakable household articles. If the movement takes place late in the season

[1] The remainder of this and the next paragraph are from Bull. 51, p. 125.
[2] Boletin de la Comision de la Parasitologia Agricola, vol. 2, pt. 2, pp. 45–58.

this cottonseed or sacks used in infested fields may easily be the means of spreading the insect. It is thought probable that a sporadic infestation at Jackson, Miss., in 1908, originated by such means from the heavily infested district around Fayette, Miss.

## UNEXPLAINED SPORADIC OCCURRENCES.

Infestations at Wichita Falls and Paris, Tex., in 1904, far removed from other infestations, can not be explained. A reported infestation in 1909 at Temple, Okla., is also of the same nature.

## INTENTIONAL TRANSPORTATION OF THE WEEVIL.

On several occasions it has been found that the boll weevil has been carried into uninfested territory purposely. In some cases the intention has been merely to exhibit live specimens and in others to test supposed remedies. Whatever the purpose of these introductions may be, the practice must be strongly condemned. It is very likely to result in the infestation of localities many years in advance of the time the weevil would reach them by natural means. The result would be a great and unnecessary loss, not only to cotton planters, but to merchants and others dependent upon the cotton trade. In this connection attention is directed to the fact that a Federal statute prohibits the interstate shipment of the boll weevil, as well as other important insect pests, and prescribes heavy penalties.[1] This act is reprinted in part, under the heading "Legal Restrictions," on a subsequent page.

In addition to the Federal legislation on this subject practically all of the States in the cotton belt have statutes which prohibit the importation or having in possession of live boll weevils for any purpose whatever. (See the section at the end of this bulletin.)

## HIBERNATION.[2]

There are many popular misconceptions regarding the manner in which the boll weevil passes the winter. For this reason we take the opportunity to point out some general considerations about hibernation.

Many forms of animal life suspend activity during the winter. This is the case with the boll weevil and many other insects, as well as with certain other animals. During this period of inactivity the animals which hibernate derive sufficient nourishment from a supply stored within the body to maintain life. They obtain no other form of food. In fact, the hibernation period coincides more or less with the periods in which the native food supply is absent. The temperatures which kill the cotton plant force the boll weevil into winter quarters, where it remains with suspended animation until spring. Almost coincident with the first sprouting of cotton we find the weevils leaving their winter quarters and moving about in the fields.

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[1] An act to prohibit importation or interstate transportation of insect pests, etc. (Act of Mar. 3, 1905, ch. 1501, 33 Stat. L., 1269.)

[2] Two excellent publications on the hibernation of the boll weevil have been issued. These are: "The Hibernation of the Boll Weevil in Central Louisiana," by Wilmon Newell and M. S. Dougherty (Cir. 31, La. Crop Pest Commission), and "Hibernation of the Mexican Cotton-Boll Weevil," by W. E. Hinds and W. W. Yothers (Bul. 77, Bur. Ent., U. S. Dept. Agr.).

The long absence of the weevils from the cotton fields has led superficial observers to believe that the weevils pass the egg stage in the cotton seed. Such persons point out the fact that the weevils are found in seed houses and appear most abundantly in the fields near these buildings, and also that they have found insect larvæ in the seed. As a matter of fact, the insects found in the cotton seed are not boll weevils, but other species which feed upon dried seeds and similar vegetable matter. The appearance of the early weevils in the vicinity of seed houses is due entirely to the fact that the protection offered there attracts many in the fall. Careful observations throughout the winter have shown that the boll weevil remains inactive except for very slight movements during very warm periods and that it does not breed in or feed upon cotton seed.

As explained in another portion of the bulletin, the hibernation period is defined by the continuance of mean temperatures within what we define as the zone of hibernation. This zone has as its upper limit the mean temperature above which, if continued for any considerable period, the life activities must be resumed, and has for its lower limit the absolute temperature below which no weevil can live for even a short time. For all practical purposes the hibernation zone lies between 56° and 12° F.

## METHODS OF STUDY OF HIBERNATION.

In studying several features of the hibernation of the boll weevil the practice has been to utilize large cages covered with wire screen which were placed in the cotton fields. (See Pl. X, *b*.) No cotton was grown in these cages, but at different dates in the fall large numbers of weevils collected in the adjoining cotton were placed in the cages. It has been considered that the rate of survival of weevils in these cages installed chronologically is an index to the number of weevils that actually survive under natural conditions. It has thus been considered that with 1,000 weevils in a cage installed October 1, which showed a survival of 10 per cent, and a cage containing 1,000 weevils installed on September 15, which showed a survival of 5 per cent, twice as many weevils would have survived the destruction of the plants on October 1 as on September 15. Although there is no doubt that this method gives a fairly accurate index, there is one objection that can be made to it. This objection is that the number of weevils leaving the field to go into hibernation as the season progresses, the number dying in the fields, and the number maturing there are not taken into consideration as the calculations have been made. On September 15 none of the weevils in the field would have entered into hibernation. By the 1st of October, however, a certain number would have left the field, and such weevils would not be represented in the collections made for the cage installed on October 1. It is not known whether the weevils which remain in the fields late are more or less hardy than those which leave early to find hibernating quarters. The indications, however, are that the stronger and more active weevils—that is, those more likely to survive the winter—are the ones which do not go into hibernation at an early date. Nevertheless the number that may have gone into hibernation between the dates of the installation of the various cages, the number that died from natural causes, and the number that matured in the fields during that

time must be considered. As a matter of fact, the total number of weevils in a locality on October 1 would be the number present in the cotton fields on September 15, less the total number dying between September 15 and October 1, and less the number leaving the field to enter into hibernation during that period, plus those that matured during the same time. It is likely that the number of weevils maturing is generally sufficient to offset the number that die from natural causes. This leaves only the weevils which escape collection by entering into hibernation to be considered. As there is no way in which this number can be determined, the method we have followed, which ignores them altogether, is the closest approximation we can make to a determination of the actual number of weevils which succeed in passing the winter after the destruction of the food plants in the fall.

It is to be noted that the possible error in the interpretation of the results of hibernation experiments becomes greater in the case of the cages installed late in the season. As the season advances more and more of the weevils leave the fields and thus pass out of consideration in connection with the number collected and placed in the cages.

The hibernation experiments conducted have dealt with 181,932 weevils utilized in seven different seasons in seven localities throughout the infested territory.

## ENTRANCE INTO HIBERNATION.

### SOURCES OF WEEVILS ENTERING HIBERNATION.[1]

Following the maturity of a considerable portion of the crop of bolls, and usually in connection with the occurrence of a heavy rainfall, a renewed growth of the plant commonly produces an abundance of squares. It is this late top growth of the plant, which serves no good purpose so far as further production of cotton is concerned, that is primarily responsible in most fields for the needlessly large number of weevils produced between the time of maturity of the crop and the usual time of destruction of the plants by frost. A large proportion of the weevils which become adults before September 1 may be expected to die, either as cold weather comes on or during the early part of the winter season. There is no particular hibernation brood, but representatives of all generations may survive and enter hibernation, as has been shown by figure 14 in the discussion of the life cycle.

### STAGES ENTERING HIBERNATION.[2]

The reproductive activity of the weevil continues steadily until the plants are destroyed by frost, but it gradually decreases coincidently with the gradual decrease in temperature. All stages from the egg to the adult may be found in both squares and bolls, even after frosts have occurred. The immature stages in squares are not immediately killed unless the freeze is exceptionally severe, and in some localities many of these survive to reach maturity and to emerge during the following spring. Usually, however, only those which are nearly adult at the time frost occurs may be expected to

[1] The matter in this section is mainly extracted from Bull. 77, Bureau of Entomology, pp. 12, 13.
[2] The matter in this section is largely extracted from Bull. 77, pp. 13, 14.

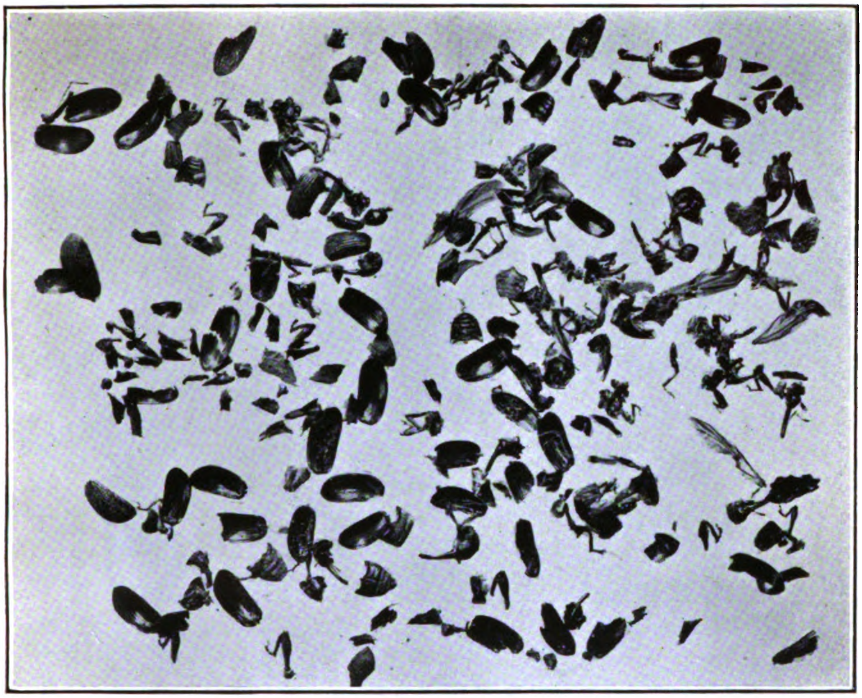

FIG. *a*.—BOLL-WEEVIL REMAINS AFTER PASSING THROUGH FAN FROM GIN. (ORIGINAL.)

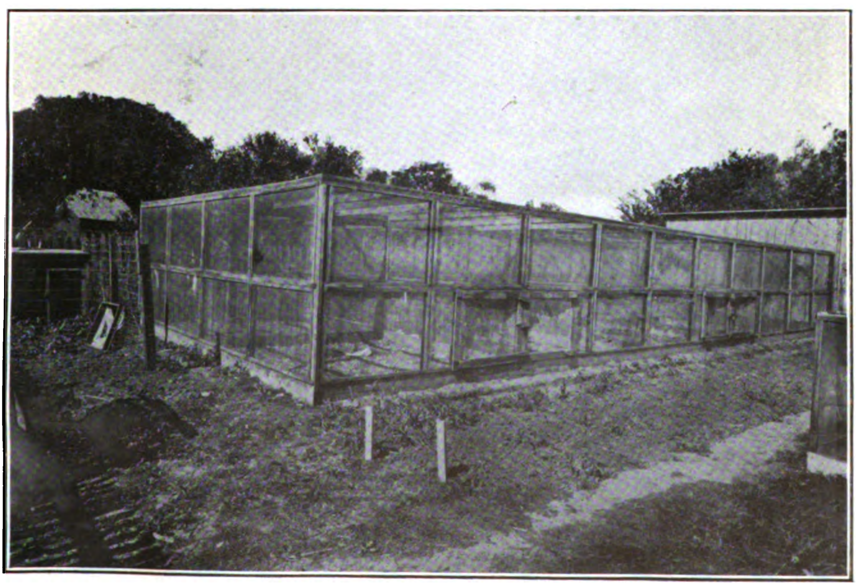

FIG. *b*.—TEN-SECTION HIBERNATION CAGE. (ORIGINAL.)

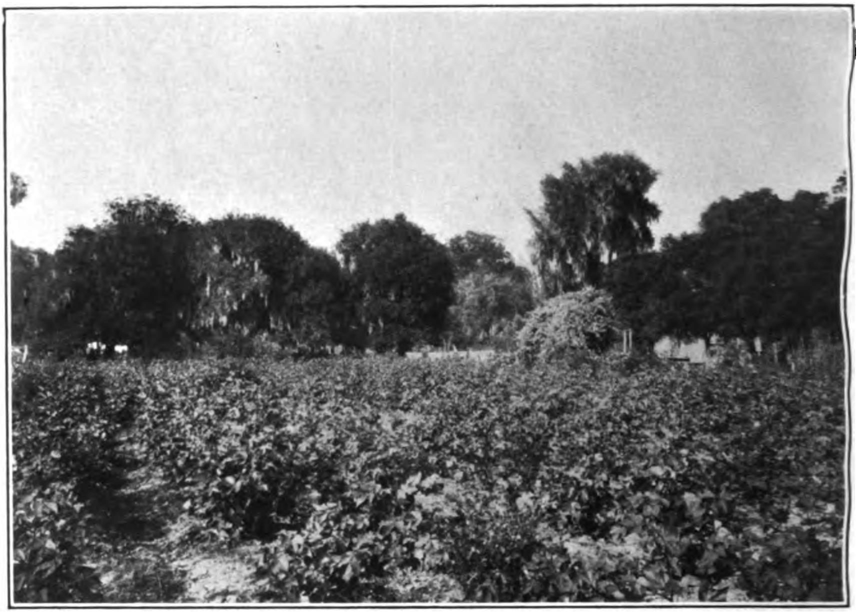

*Fig. a.*—Cotton field adjacent to timber covered with Spanish moss. (Original.)

*Fig. b.*—Proximity of moss-laden trees, conducing to high infestation by weevil. (Original.)

HIBERNATION CONDITIONS FOR THE BOLL WEEVIL.

emerge. These might emerge upon warm days following the colder weather, but in the absence of a fresh food supply would soon die. In the fall of 1903 Prof. E. D. Sanderson, in an examination of 700 squares at the middle of November, found 79 eggs, which means that 11 per cent of the squares contained eggs. In an examination of 1,600 squares he states that 366 larvæ were found, showing that about 23 per cent of the squares contained larvæ at the time of entrance into hibernation.[1] Some stages may survive in squares for a short time after the freeze, but there are few records of weevils entering hibernation as immature stages in squares and surviving to emerge therefrom in the spring. These stages are therefore unimportant from an economic point of view.

With immature stages entering hibernation in bolls, the case is quite different from that in squares. Very large numbers of weevils enter upon the period of hibernation as immature stages and during many seasons, especially in the southern part of the State, a large percentage of these complete their development, and many survive until time for their emergence in the spring. Immature stages in bolls have been found alive at Victoria, Tex., as late as February 17.

### TIME OF ENTERING HIBERNATION.

Hibernation begins when the temperature reaches a point between 60° and 56° F. The exact point will be higher with a high percentage of humidity and lower with a low percentage of humidity.

According to the observations of Messrs. Newell and Dougherty.[2] at Mansura, La., in 1908, entrance into hibernation began on October 28. The mean temperature for 10 days preceding that date was 63.7° F., but the minimum dropped from 46° to 31° F. on the day the weevils began to enter into hibernation.

The action of the weevils in securing shelter from approaching cold is instinctive rather than intelligent. It is probably true that they have no such sense of sight as we commonly understand from the use of that word and that their selection of shelter is not at all guided by that sense. We mean by this that a weevil on a cotton plant can not see at any distance shelter which might be attractive to it and thereupon fly from the plant to the shelter. Cold nights with a temperature between 40° and 50° F., succeeded by warm still days, such as occur commonly in the fall, seem to stimulate the weevils to an unusual activity both in flight and in crawling. It seems possible that they have an instinctive knowledge of the approach of temperature conditions from which they must secure shelter, but it is also true that many weevils remain active upon plants for some time after the plants have been destroyed by frost and frequently until several weeks after other individuals have entered hibernation. In speaking of entering hibernation, therefore, we mean the entrance of the weevils upon a period of comparative if not complete inactivity. Their action in securing shelter is gradual and governed primarily by the degree of protection from the cold which they may receive. If early in the season a weevil accidentally finds shelter which gives it exceptional protection from the cold it will likewise be exceptionally protected from heat and therefore less likely than are other less

[1] Bull. 63, Bureau of Entomology, U. S. Dept. of Agriculture.
[2] Cir. 31, Lousiana Crop Pest Commission, p. 170.

fortunate individuals to resume its activity upon warm days. If at first the shelter which weevils find is only slight they will be easily influenced by succeeding warmth, and in another period of activity will be likely to find better protection. Their flight upon warm days undoubtedly leaves large numbers of them outside of the cotton fields, where they are more likely to find favorable shelter than within the fields themselves.

From this explanation it will be understood that it is rarely possible to indicate by a single date the time when weevils enter hibernation. It may be better expressed as a period within the limits of which a large majority, though possibly not all, weevils may seek shelter. Naturally this time varies according to the seasonal temperature conditions, so that in a certain locality it may occur several weeks earlier in one season than in another. It is also evident that differences in temperature conditions due to latitude or altitude will cause a similar variation in the time when weevils enter hibernation.[1]

In Table XXXIII are shown the times of the year in which the weevils entered hibernation in the experiments of 1903 to 1906, together with the temperature conditions prevailing. The table shows the relationships between humidity and temperature and the length of the period of entrance into hibernation. In short, it may be stated that the lower the mean temperature the shorter the period of entrance. Sufficient information is not at hand to show positively the influence of humidity, but it is evident that there is a decided influence.

TABLE XXXIII.—*Period of entrance of the boll weevil into hibernation and meteorological conditions.*

| Year. | Locality. | Period. | | Mean temperature. | Mean humidity. |
|---|---|---|---|---|---|
| | | Limits. | Days. | | |
| | | | | °F. | Per cent. |
| 1905 | Dallas, Tex | Nov. 29–Dec. 8 | 10 | 40.5 | 64.8 |
| 1903 | College Station, Tex | Nov. 15–27 | 13 | 49.5 | |
| 1903 | Victoria, Tex | Nov. 15–30 | 16 | 53.0 | |
| 1905 | .....do | Nov. 30–Dec. 18 | 19 | 50.0 | |
| 1904 | Corsicana, Tex | Nov. 10–Dec. 5 | 26 | 55.0 | |
| 1906 | Dallas, Tex | Nov. 12–Dec. 8 | 27 | 53.0 | 73.1 |
| 1904 | Victoria, Tex | Nov. 11–Dec. 8 | 28 | 57.5 | 79.3 |
| 1906 | .....do | Nov. 9–Dec. 21 | 43 | 60.4 | |

Weevils can not be forced to hibernate when conditions do not normally induce hibernation. If kept without food, they will starve. The real bearing of this statement will be brought out later in connection with the summaries of the survival in its relation to the time of beginning hibernation. (See Table XLVI.)

## NUMBER OF ADULT WEEVILS ENTERING HIBERNATION.

Of course the number of adult weevils entering hibernation is a variable quantity, owing to the differences in the percentage of infestation in various regions and seasons. Examinations in heavily infested regions have shown averages as high as 58,000 adult weevils

[1] This and the preceding paragraph are remodeled from Bull. No. 77, Bureau of Entomology.

per acre in the middle of November. In this connection it is interesting to note the progress of entrance into hibernation as shown by Table XXXIV, based on investigations made at Dallas in fields with an average of 8,300 plants per acre.

TABLE XXXIV.—*Number of boll weevils per acre upon stalks at different dates at Dallas, Tex.*[1]

| Date. | Plants examined. | Living weevils found. | Living weevils per acre. |
|---|---|---|---|
| 1906. | | | |
| Oct. 12 | 110 | 122 | 9,205 |
| Oct. 31 to Nov. 3 | 84 | 190 | 18,774 |
| Nov. 10 | 60 | 106 | 14,663 |
| Nov. 20 | 35 | 29 | 6,877 |
| Nov. 22 | 35 | 27 | 6,403 |
| Dec. 1 | 36 | 10 | 2,306 |
| Dec. 18 | 35 | 5 | 1,186 |
| 1907. | | | |
| Jan. 21 | 35 | 3 | 711 |

[1] From Bull. 77, Bureau of Entomology, p. 18.

In connection with this subject we include also Table XXXV for the same period, showing the occurrence of the weevils under shelter on the ground in the cotton fields.

TABLE XXXV.—*Number of weevils under rubbish on ground at Dallas, Tex.*[2]

| Field. | Date examined. | Portion of acre examined. | Weevils found— | | Total per acre. | Percentage alive. | Remarks. |
|---|---|---|---|---|---|---|---|
| | | | Alive. | Dead. | | | |
| | 1906. | | | | | | |
| A | Nov. 15 | 22 plants. | 4 | 0 | 1,450 | 100.0 | In cracks of ground around bases of plants. |
| A | ...do.... | 1/264 | 4 | 0 | 1,056 | 100.0 | Under rubbish on ground. |
| A | Nov. 22 | 1/347 | 8 | 0 | 2,776 | 100.0 | Do. |
| A | Dec. 18 | 1/264 | 5 | 14 | 5,016 | 26.3 | Do. |
| | 1907. | | | | | | |
| B | Jan. 11 | 10/8384 | 5 | 2 | 5,870 | 71.4 | Northeast corner of field. |
| C | Jan. 29 | 10/6236 | 1 | 1 | 1,247 | 50.0 | Middle of field. |
| C | ...do.... | 10/8384 | 2 | 2 | 3,354 | 50.0 | Near southwestern edge. |

[2] This table and the following paragraph are taken from Bull. 77, Bureau of Entomology, p. 20.

The sum total of weevils found both on plants and on the ground on November 22 shows an average of slightly more than 9,000 weevils per acre, all of which were alive. On December 18 the number that could be accounted for was between 6,000 and 7,000 per acre on the same ground which had been previously examined. On the former date more than two-thirds of the weevils were still upon the plants. On the latter date nearly five-sixths of them were on the ground, and among those on the ground only 26 per cent were living. These figures show that between November 22 and December 18 a very large mortality had occurred among weevils which had entered hibernation, and especially among those which had sought shelter under rubbish upon the surface of the black-waxy soil of field A.

## SHELTER DURING HIBERNATION.

Boll weevils in seeking shelter from the cold will enter all kinds of places which might afford shelter. The following statements are quoted from Prof. E. D. Sanderson:[1]

The observations by Prof. Conradi at College Station, Tex., in the early winter of 1903, probably indicate some of the normal places for hibernation—that is, under dead leaves, in old cotton brush, and under loose bark. In the hibernation cages, where the weevils were furnished an abundance of rubbish, it was found that many of them which were hibernating successfully had crawled into the cavities made by borers in dead wood and in similar positions where they were well protected. It has been often noticed that in a wooded country the weevils appear first in spring along the borders of fields next to the woods and gradually work inward from the edges, so that it seems probable that in a wooded country most of them hibernate in woodland. Around outbuildings and barns also are found favorable places, as there is always more or less rubbish and protection in such situations. In 1903 more than five times as many weevils were found in a piece of cotton near the college barn, where cotton had been grown the previous year, than were found in any other locality in that neighborhood. It is also noticeable that weevils are always more numerous near gins than at a distance from them.

It is noticeable that weevils are much more abundant where cotton is planted in fields where sorghum stubble has been allowed to remain all winter adjoining a last year's cotton field.

Professor Mally has given the observations of Mr. Teltschick upon finding weevils hibernating in the crevices of the soil around the cotton stalks and roots, at a depth of 3 inches. On March 7, 1901, a raw, windy day, upon 35 stalks, he found 7 live and 2 dead weevils from 1 to 3 inches below the surface. In September, 1902, he stated that he had again found weevils in a similar situation during the previous spring, but not as many of them as in 1901. Mr. Teltschick recently writes as follows:

"I found but few weevils in crevices around stalks during the last two winters, partly because there were no crevices (frequent rains filling them up as soon as formed) and partly because freezes were severe enough to keep cotton from coming out during any part of the last two winters; whereas in 1900 we had neither rain enough to fill up crevices nor frost enough to keep cotton from budding out at intervals at the base of the stalk, which latter fact accounts, no doubt, for the relatively large number of weevils found within the crevices."

Where the cotton stalks are allowed to stand throughout the winter they furnish the weevils both the means of subsistence late in the fall and an abundance of favorable hibernation places throughout the field. The prospects of successful hibernation are thereby multiplied many times, and, furthermore, the weevils are already distributed over the field when they first become active in the spring. The grass and weeds which almost invariably abound along fence lines are exceedingly favorable to the hibernation of many weevils, so that it will be found generally true that the worst line of infestation in the spring proceeds from the outer edges of the field inward. Where cotton and corn are grown in adjacent fields, or where, as is sometimes the case, the two are more or less mixed in the same field, many weevils find favorable shelter in the husks and stalks of the corn. An especially favored place is said by Mr. E. A. Schwarz to be in the longitudinal groove in the stalk and within the shelter of the clasping base of the leaf. Perhaps the most favorable of all hibernating conditions are to be found among the leaves and rubbish abounding in the edges of timber adjoining cotton fields and in Spanish moss. From such sources the weevils are known to come in large numbers in the spring. Sorghum stubble, which collects débris blown about by the wind, is also very favorable for hibernation.

[1] Bull. 63, Bureau of Entomology, U. S. Dept. Agriculture, pp. 18-19.

*Fig. a.*—Standing dead timber and forest environment favorable for hibernation of weevils. (Original.)

*Fig. b.*—Litter in forest, suitable for hibernation of weevils. (Original.)

HIBERNATION CONDITIONS FOR THE BOLL WEEVIL.

*Fig. a.*—Spanish moss on trees; very favorable for hibernation of weevils. (Original.)

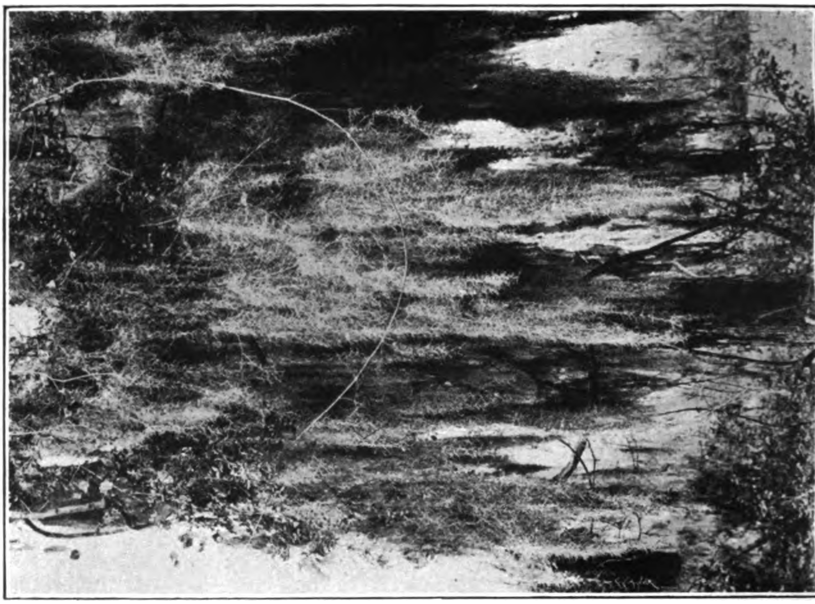

*Fig. b.*—Density of Spanish moss as a protection to weevils in hibernation. (Original.)

HIBERNATION CONDITIONS FOR THE BOLL WEEVIL.

Attention has already been called to the fact that many stages enter the period of hibernation in an immature condition in unopened bolls. That adult weevils hibernate entirely within the protection afforded by the bracts and hulls of bolls has been abundantly demonstrated. Messrs. Hinds and Yothers[1] showed, however, that the percentage of live stages in bolls decreased rapidly during the winter, thus proving that the bolls do not furnish perfect hibernation shelter. Their results may be summarized as follows:

TABLE XXXVI.—*Seasonal decrease of live stages of the boll weevil in bolls; percentage of bolls containing live stages.*

| | |
|---|---|
| December | 36.00 |
| January | 1.15 |
| February | 0.29 |
| March | 0.00 |

As would be expected, it was found that there was a greater percentage of survival in bolls in southern localities.

During an ordinary season it can not be doubted that a large majority of the weevils which survive find some other shelter than the bolls hanging upon the plants. It is not, however, as easy a matter to find weevils in rubbish scattered upon the ground as in bolls. It is necessary to collect the rubbish very carefully and sift it over cloth or paper to separate the weevils from the trash. In this way it has been found that weevils hibernate extensively in the leaf and grass rubbish distributed throughout the field. Naturally, the cleaner the field in the fall the smaller will be their chances of finding favorable shelter during the winter.[2] (Pl. XII, *b*.)

Standing trees are a common sight in cotton fields, and while the records of weevils found hibernating under bark are but few, they are sufficient to indicate that these trees may be rather important factors where they occur in considerable numbers. (Pl. XII, *a*.)

Where the Spanish moss (*Tillandsia usneoides*) occurs, as in the bottom lands in the coast section of Texas and in the southern portions of the Gulf States generally, weevils find exceptionally favorable shelter. Many examinations of large quantities of moss have been made to ascertain the importance of this form of shelter. The maximum number of weevils per ton of moss is recorded by Messrs. Newell and Dougherty (1909) as 3,158 in moss collected from an elm tree located in a swamp at Mansura, La., December 23, 1908. The moss was at a height of 15 feet. The tree was one-fourth of a mile from the nearest cotton field. On January 9, 1910, Mr. C. E. Hood found at Mansura 924 boll weevils and 2,156 boll-weevil parasites per ton of moss collected at from 1 to 8 feet above the ground. The weevils seem to prefer the festoons of green-hanging moss to the dead masses. (See Pls. XI, XIII.)

Cornfields adjoining cotton, or cornstalks scattered throughout cotton fields may shelter many weevils. This was first noticed by Mr. E. A. Schwarz at Victoria, Tex., in the winter of 1901–2, and has since been corroborated by a number of observers. Several examinations have been made of haystacks in the vicinity of cotton.

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[1] Bull. 77, Bureau of Entomology.
[2] This paragraph and the remainder of the discussion in the present section is modified from Bull. 77, Bureau of Entomology, pp. 30–33, 41, 42.

This is a task quite comparable with that of seeking for the proverbial needle, and it is not surprising that the results have been very meager. The fact, however, that traces of weevils have been found in these examinations indicates that weevils may find shelter under such conditions.

Farmyards, seed houses, barns, ginneries, and oil mills also afford favorable shelter for weevils. Especially in ginneries and seed houses the weevils become concentrated with the cotton or seed and frequently may be found in large numbers within or around these buildings. In connection with this subject the reader is referred to a fuller discussion of the significance of ginneries and oil mills in the distribution of weevils and of the methods recommended for controlling them.[1]

In order to have a basis of comparison of the various kinds of shelter, many cage experiments have been conducted. In Table XXXVII will be found a comparison of the survival in the cages at Keatchie, La., for weevils installed November 23 and 29.

TABLE XXXVII.—*Favorable conditions for hibernation determined by rank in percentage of weevils surviving at Keatchie, La., in 1905–6.*[1]

| Nature of shelter. | Weevils put in. | Weevils survived. | |
|---|---|---|---|
| | | Number. | Per cent. |
| Ordinary field stalks, grass, etc | 2,000 | 93 | 4.65 |
| Brush, leaves, stumps, logs; stalks standing | 2,500 | 89 | 3.56 |
| Same as above, but stalks removed | 3,300 | 70 | 2.12 |
| Cotton seed, piled but uncovered; stalks standing | 2,000 | 30 | 1.50 |
| Absolutely bare ground | 2,000 | 30 | 1.50 |
| Cotton seed piled and covered; stalks left standing | 2,000 | 23 | 1.15 |

[1] From Bull. 77, Bureau of Entomology, p. 42.

It is evident from these observations that ordinary field conditions where stalks are allowed to stand together with the grass and leaves littered over the ground are as favorable as any other for successful hibernation. One fact should be emphasized in regard to classes of shelter which have been mentioned as occurring within cotton fields, i. e., that it is possible, as a rule, to destroy or remove practically all of them. Undoubtedly the burning of cotton stalks, weeds, grass, and other rubbish is the easiest and most effective method of destruction where it can be practiced. Next to this in importance would be the destruction of the stalks by a stalk chopper and plowing under all the rubbish. In the latter case it must be stated that many weevils which, under dry conditions, are buried not more than 2 inches will be able to escape through the soil and may then find shelter near, if not within, the field.

[1] Farmers' Bull. 209, U. S. Dept. of Agriculture, "Controlling the Cotton Boll Weevil in Cotton Seed and at Ginneries."

## ACTIVITY DURING THE HIBERNATION PERIOD.

It is natural to expect that during warm periods of winter the temperature will rise to a point which forces the weevils into activity. Of course, the weevils under the lightest shelter are the ones which first become active. It is these warm periods which cause the intermittent development of the immature stages in dry bolls left in the fields. In some winters the hibernation is incomplete throughout the cotton belt, and in the extreme South it is probably so almost every winter. This same temperature condition is responsible for the growth of sprout cotton, which affords food in the warm periods. Observations were made in January, 1907, on weevils feeding on sprout cotton at Victoria, Tex., at a mean temperature of 67° F.

## DURATION OF HIBERNATION PERIOD.

### AVERAGE LENGTH OF HIBERNATION PERIOD.

Many factors must be considered in arriving at the average length of the hibernation period. The time of entrance, condition of the weevils on entering, temperature and humidity before and during hibernation, and nature of shelter, all have a decided effect upon the duration of hibernation. In a series of condensed summaries we have attempted to show how some of these factors act.

In Table XXXVIII is to be found a general summary of the nine large experiments conducted, with the extreme variations in each series. From this table it appears that in the years 1906 to 1911 the hibernation period has ranged between 62 and 255 days, and that in 1909 the range fell short only 1 day of this maximum range. It also appears that the average duration in Texas is 26 days shorter than in Louisiana. The period of emergence extends from February 15 to July 1.

TABLE XXXVIII.—*Extremes of variation in duration of hibernation by the boll weevil.*

| Place. | Total number weevils emerged. | Total number weevil days. | Minimum period. | Maximum period. | Minimum average. | Maximum average. | Average of averages. | Earliest emergence. | Latest emergence. |
|---|---|---|---|---|---|---|---|---|---|
| | | | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | | |
| Keatchie, La., 1906 | 731 | 114,192 | 108 | 222 | 136 | 178 | 156 | March 22 | June 28. |
| Mansura, La., 1909 | 3,260 | 516,067 | 62 | 254 | 94 | 199 | 156 | February 21. | June 29. |
| Mansura, La., 1910 | 1,038 | 170,212 | 86 | 232 | 114 | 217 | 164 | February 15. | June 15. |
| Tallulah, La., 1910 | 317 | 58,245 | 103 | 237 | 126 | 224 | 183 | February 15. | June 27. |
| Tallulah, La., 1911 | 46 | 6,587 | 107 | 231 | 118 | 158 | 143 | February 15. | June 4. |
| Louisiana average | 5,392 | 865,303 | 62 | 254 | 94 | 224 | 160 | February 15. | June 29. |
| Victoria, Tex., 1907 | 3,028 | 383,797 | 92 | 223 | 95 | 146 | 126 | February 28. | June 15. |
| Calvert, Tex., 1907 | 1,842 | 255,831 | 91 | 255 | 100 | 195 | 138 | March 4 | July 1. |
| Dallas, Tex., 1907 | 3,462 | 481,271 | 85 | 233 | 98 | 168 | 138 | March 1 | June 19. |
| Dallas, Tex., 1908 | 118 | 17,839 | 113 | 217 | 121 | 170 | 151 | March 2 | June 16. |
| Texas average | 8,450 | 1,138,738 | 91 | 255 | 98 | 195 | 134 | February 28. | July 1. |
| Grand total | 13,842 | 2,004,041 | 62 | 255 | 94 | 224 | 144 | February 15. | July 1. |

TABLE XXXIX.—*Average length of hibernation period of the boll weevil as related to date of installation.*

| Place. | Time of installation, Sept. 16-30. | | Time of installation, Oct. 1-15. | | Time of installation, Oct. 16-31. | | Time of installation, Nov. 1-15. | | Time of installation, Nov. 16-30. | | Time of installation, Dec. 1-15. | | Time of installation, Dec. 16-31. | | Average hibernation. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length of hibernation. | Emerged. | Length of hibernation. | Emerged. | Length of hibernation. | Emerged. | Length of hibernation. | Emerged. | Length of hibernation. | Emerged. | Length of hibernation. | Emerged. | Length of hibernation. | Emerged. | |
| | *Days.* | | *Days.* | | *Days.* | | *Days.* | | *Days.* | | *Days.* | | *Days.* | | *Days.* |
| Keatchie, La., 1906 | | | | | | | | | 158 | May 1 | 146 | Mar. 1 | | | |
| Mansura, La., 1909 | 183 | Mar. 31 | 170 | Mar. 27 | 185 | Apr. 30 | 157 | Apr. 11 | 143 | Apr. 15 | 124 | Apr. 13 | 94 | Mar. 26 | |
| Mansura, La., 1910 | 217 | May 3 | 180 | Apr. 8 | 165 | Apr. 7 | 162 | Apr. 22 | 159 | Apr. 26 | 146 | May 5 | | | |
| Tallulah, La., 1910 | 224 | May 5 | 219 | May 17 | 173 | Apr. 15 | 162 | Apr. 16 | 145 | Apr. 20 | | (1) | | | |
| Tallulah, La., 1911 | | | 156 | Mar. 20 | 125 | Mar. 5 | | (1) | | (1) | | (1) | | | |
| Louisiana weighted average | 185 | Apr. 23 | 190 | Apr. 16 | 183 | Apr. 24 | 158 | Apr. 15 | 151 | Apr. 23 | 129 | Apr. 16 | 94 | Mar. 26 | 160 |
| Victoria, Tex., 1907 | | | | | 139 | Mar. 14 | 132 | Mar. 22 | 113 | Mar. 19 | | | | | |
| Calvert, Tex., 1907 | | | 166 | Mar. 28 | 175 | Apr. 18 | 142 | Apr. 1 | 119 | Mar. 24 | 100 | Mar. 13 | | | |
| Dallas, Tex., 1907 | | | 168 | Mar. 29 | 149 | Mar. 20 | 135 | Mar. 26 | 125 | Mar. 29 | 98 | Mar. 14 | | | |
| Dallas, Tex., 1908 | 170 | Mar. 17 | 160 | Mar. 21 | 157 | Apr. 1 | 141 | Mar. 30 | 122 | Mar. 20 | | | | | |
| Texas weighted average | 170 | Mar. 17 | 166 | Mar. 21 | 151 | Mar. 23 | 135 | Mar. 23 | 116 | Mar. 9 | 98 | Mar. 14 | | | 134 |
| Grand weighted average | 176 | Mar. 18 | 180 | Apr. 4 | 168 | Apr. 9 | 139 | Mar. 27 | 130 | Apr. 2 | 126 | Apr. 13 | 94 | Mar. 26 | 144 |

[1] No emergence.

Knowing that the time of entrance affects the percentage of survival, it is also reasonable to expect an effect upon the duration of the hibernation period. Table XXXIX has been constructed to show the average duration and average date of emergence at each locality for all weevils entering hibernation in each half month during the several seasons of the experiments. It will be noted that the length of the period, with a few minor exceptions, decreases in accordance with the lateness of entrance. It is very strikingly shown that in any given period of entrance the duration in Texas is considerably shorter than in Louisiana. On the other hand, it is impossible to show from this table any progression in the average date of emergence.

The diagram (fig. 22) shows graphically the correspondence between date of installation and period of hibernation and emphasizes the differences between Texas and Louisiana.

### RELATION OF SHELTER TO DURATION OF HIBERNATION.

That the nature of the hibernating quarters has a direct bearing upon the duration of the period is to be gathered from the records of Messrs. Newell and Dougherty made at Mansura, La., in 1909, which are abstracted below:

TABLE XL.—*Comparison of length of hibernation of the boll weevil in different shelters at Mansura, La., 1909.*[1]

| Date started 1908. | Nature of hibernation quarters. | Location of cage. | Number of weevils contained. | Number of weevils surviving winter. | Average number of days in hibernation. | Average date of emergence. |
|---|---|---|---|---|---|---|
| October 26 | Average | In open field | 1,294 | 325 | 169.1 | April 13 |
| Do | do | In swamp | 1,142 | 162 | 173.3 | April 17 |
| Do | Moss | In open field | 1,214 | 409 | 190.9 | May 4 |
| Do | do | In swamp | 938 | 408 | 199.4 | May 13 |
| Total | | | 4,588 | 1,304 | | |
| Average | | | | | 185.0 | April 28 |

[1] This table and the following statements are extracted from Cir. 31, State Crop Pest Commission of Louisiana.

Consideration of Table XL reveals the interesting fact that weevils hibernating in the cool, shaded situations in timber remained in hibernation an average of about seven days longer than those hibernating in the open field. Weevils which hibernated in moss in the swamp remained in hibernation practically 200 days, and those which passed the winter in moss on trees in the open field remained in hibernation 191 days. In marked contrast to this the weevils that hibernated in a general assortment of materials in the open field remained in hibernation only 169 days, though gathered from the cotton fields at exactly the same date in the fall of 1908. This proves the dangerous nature of the moss, for it really causes the weevils in it to remain in hibernation for nearly a month longer than they would if hibernating in other materials.

Table XL also illustrates the influence of temperature upon the duration of the hibernation period, for there is no doubt that it is the temper-

ature prevailing in the exact spot where the individual weevils are hibernating that determines the date of emergence from hibernation. Piles of grass in the open field are warmed by the sun in February and March, and the weevils emerge from them at that time. The shaded places of the forest or swamp are cool and damp, and they do not reach an

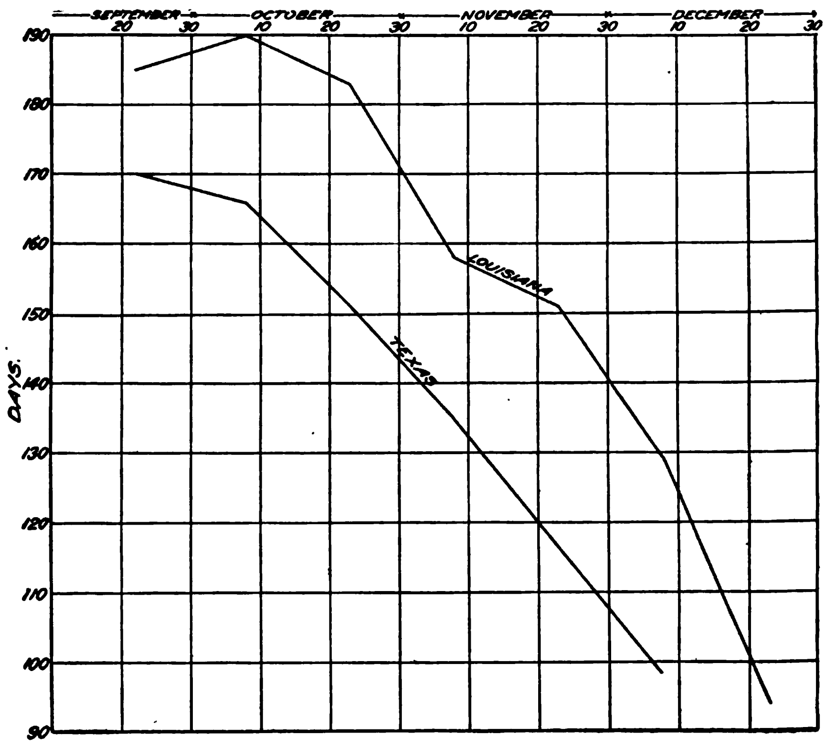



FIG. 22.—Diagram illustrating average length of hibernation period of the boll weevil as related to date of entering hibernation. (Original.)

equivalent temperature until some weeks afterwards, and the weevils consequently emerge later in such places than in the open fields. The bunches of moss are so resistant to heat that even in the hottest days of summer they are very noticeably cooler than the air.

## EMERGENCE FROM HIBERNATION.

### TIME OF EMERGENCE.

The time of emergence of the boll weevil from hibernation ranges from February 15 to July 1. It is necessary to discuss the conditions which cause this irregularity. A careful study of all the series of experiments to determine the immediate causes for the first decided impulse to emerge has resulted in the following conclusion: That the

time of emergence varies with the total effective temperature and the rainfall. Computing the total effective temperature from January 1 in daily units of mean temperature above the mean of 56° F. (average zero of effective temperature) it is found that approximately 172.6° F. of effective temperature and 5.1 inches of rain are necessary to bring the weevils out of hibernation in comparatively large numbers. If the rainfall is greater than 5.1 inches the necessary effective

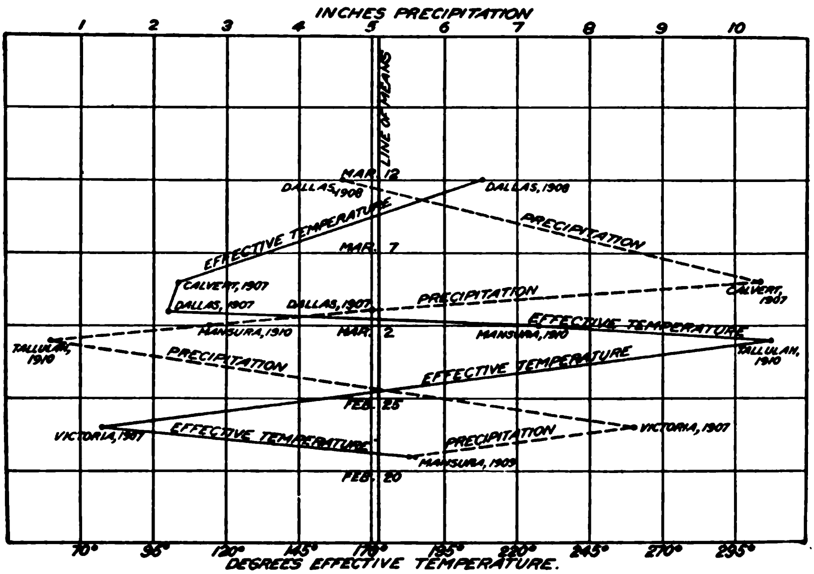



FIG. 23.—Diagram illustrating relations of effective temperature and precipitation to date of beginning emergence of the boll weevil. (Original.)

temperature usually will be less than 172.6° F., and, on the other hand, if the total effective temperature is greater than 172.6° F. the necessary rainfall will usually be less than 5.1 inches. This may be seen by reference to Table XLI and by the diagram (fig. 23). Discrepancies will occur with regard to this formula and will in a large measure be due to the type of shelter or to great irregularities in the climate.

TABLE XLI.—*Relation of effective temperature and precipitation to date of beginning emergence of the boll weevil.*

| Place. | Total effective temperature from Jan. 1. | Total precipitation from Jan. 1. | Date of first extensive emergence. |
|---|---|---|---|
| | ° *F.* | *Inches.* | |
| Tallulah, 1910 | 65 | 10.5 | March 1. |
| Mansura, 1910 | 115 | 7.3 | March 2. |
| Dallas, 1908 | 160 | 6.5 | March 12. |
| Dallas, 1907 | 170 | 2.2 | March 3. |
| Mansura, 1909 | 185.5 | 5.5 | February 21. |
| Victoria, 1907 | 260 | 1.3 | February 23. |
| Calvert, 1907 | 303.7 | 2.35 | March 5. |

Figure 23 shows graphically that climate influences the time of beginning emergence. It also has a decided effect upon the subsequent emergence. In Table XLII is shown what effect the daily mean temperature has upon the hibernating weevil.

TABLE XLII.—*The relation of emergence of the boll weevil to increase in temperature at Keatchie, La., and Dallas, Tex., 1906.*[1]

| Range of temperatures (° F.). | Keatchie, La. | | Dallas, Tex. | | Total number of weevils emerged. | Per cent based on grand total emerged. |
|---|---|---|---|---|---|---|
| | Number of weevils emerging. | Per cent of total emergence. | Number of weevils emerging. | Per cent of total emergence. | | |
| 43-57 | 20 | 2.7 | 0 | 0 | 20 | 2.5 |
| 58-63 | 52 | 7.1 | 2 | 3.6 | 54 | 6.8 |
| 64-68 | 116 | 16.0 | 25 | 45.5 | 141 | 17.8 |
| 69-73 | 127 | 17.5 | 18 | 32.7 | 145 | 18.5 |
| 74-78 | 309 | 42.4 | 10 | 18.2 | 319 | 40.7 |
| 79-83 | 84 | 11.5 | 0 | 0 | 84 | 10.7 |
| 84-93 | 20 | 2.7 | 0 | 0 | 20 | 2.5 |
| Total | 728 | 100.0 | 55 | 100.0 | 783 | 100.0 |

[1] Modified from Bull. 77, Bureau of Entomology, p. 44.

The number of weevils emerging under 57° F. is very small indeed. From that point the emergence increases with the increase in temperature until a majority of the weevils have emerged. Most weevils have been found to leave their winter quarters during a temperature averaging between 64° and 78° F. At Keatchie 75 per cent and at Dallas 96 per cent of the total emergence took place between these limits. At Dallas the largest emergence occurred between temperatures of 64° and 68° F., while at Keatchie the largest emergence occurred between 74° and 78° F. In a preceding paragraph we have shown that higher temperatures are necessary to affect the weevils hibernating in Louisiana, apparently because of the heavier shelter.

### RATE OF EMERGENCE.

With a long-continued emergence period it is important to determine whether the rate of emergence is equal at all times or has its periods of retardation and acceleration. Upon charting the percentage of total emergence for each week it was noted that the Texas and Louisiana points differed considerably. On the accompanying diagram (fig. 24) the four Texas series are consolidated to give the average rate, and likewise the four Louisiana series are consolidated, while in Table XLIII the records for each locality are given. It is immediately apparent that the emergence begins much

more abruptly in Texas than in Louisiana. In Texas 25 per cent have emerged by March 12, 50 per cent by March 21, 75 per cent by April 8, and 100 per cent not until June 19. On the other hand, in Louisiana 25 per cent have not emerged until March 30, 50 per cent until April 27, 75 per cent until May 16, while 100 per cent will have emerged only by July 3. Herein lies a powerful argument for early planting. With 50 per cent of the weevils emerging after March 21 in Texas

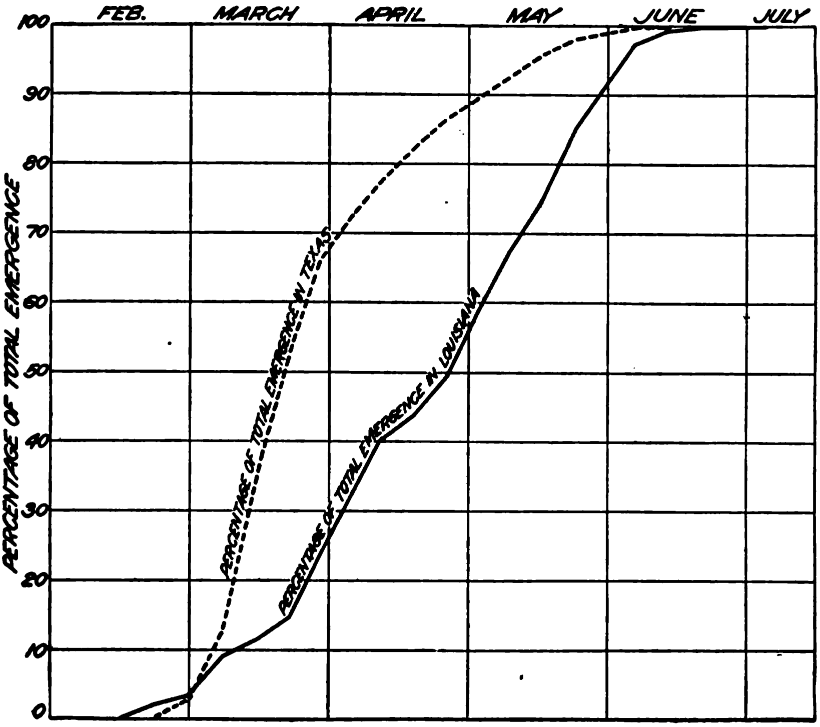



FIG. 24.—Diagram illustrating average rate of emergence of the boll weevil from hibernation in Texas and Louisiana. (Original.)

and 86 per cent emerging after the same date in Louisiana, or with 75 per cent emerging after April 8 in Texas and 64 per cent yet to emerge after the same date in Louisiana, it becomes evident that every day gained in Texas before March 21 or in Louisiana before April 8 is of immense importance in the fight against the weevil. Even later than these dates every day counts a great deal, because it is apparent that the longer planting is deferred the more weevils will be out to attack the cotton when it comes up.

TABLE XLIII.—*Percentage of total emergence of the boll weevil out at given dates.*

| Date. | Keatchie, La., 1906. | Tallulah, La., 1910. | Mansura, La., 1910. | Mansura, La., 1909. | Dallas, Tex., 1908. | Calvert, Tex., 1907. | Dallas, Tex., 1907. | Victoria, Tex., 1907. | Tallulah, La., 1911. |
|---|---|---|---|---|---|---|---|---|---|
| February 21 | 0.00 | 0.31 | 1.64 | 7.20 | 0.00 | 0.00 | 0.00 | 0.00 | 36.95 |
| February 28 | .00 | .31 | 3.28 | 10.61 | .00 | .00 | .00 | 12.01 | 36.96 |
| March 7 | .00 | 6.62 | 10.56 | 19.22 | 7.27 | 22.80 | 24.48 | 27.92 | 39.92 |
| March 14 | .00 | 10.09 | 15.69 | 19.73 | 23.63 | 31.90 | 36.36 | 48.23 | 63.83 |
| March 21 | .00 | 13.56 | 21.19 | 23.24 | 45.45 | 44.30 | 57.14 | 66.24 | 70.35 |
| March 28 | 3.93 | 23.34 | 38.05 | 30.95 | 55.45 | 57.20 | 71.72 | 79.35 | 72.52 |
| April 4 | 6.87 | 35.95 | 46.53 | 38.16 | 63.63 | 64.20 | 75.70 | 84.16 | 74.69 |
| April 11 | 24.54 | 41.95 | 49.42 | 43.87 | 68.18 | 70.40 | 81.28 | 89.58 | 81.21 |
| April 18 | 32.11 | 46.05 | 52.41 | 47.78 | 74.54 | 77.70 | 84.46 | 93.80 | 87.73 |
| April 25 | 40.67 | 48.89 | 53.86 | 56.39 | 87.27 | 79.51 | 85.74 | 95.02 | 96.42 |
| May 2 | 52.73 | 61.83 | 60.41 | 61.30 | 90.91 | 82.62 | 88.62 | 95.88 | 96.42 |
| May 9 | 60.44 | 70.66 | 72.35 | 67.51 | 91.82 | 88.73 | 92.30 | 97.50 | 98.59 |
| May 16 | 72.22 | 75.39 | 75.64 | 75.12 | 94.55 | 91.94 | 96.78 | 98.36 | 98.59 |
| May 23 | 86.41 | 88.64 | 84.77 | 82.43 | 98.18 | 94.95 | 98.76 | 98.92 | 98.59 |
| May 30 | 91.60 | 93.69 | 92.77 | 89.73 | 98.18 | 97.56 | 99.34 | 99.18 | 98.59 |
| June 6 | 97.36 | 99.05 | 98.43 | 96.83 | 99.09 | 99.17 | 99.73 | 99.90 | 100.00 |
| June 13 | 99.19 | 99.68 | 99.89 | 97.83 | 99.09 | 99.68 | 99.88 | 99.97 | 100.00 |
| June 20 | 99.61 | 99.68 | 100.00 | 98.74 | 100.00 | 99.99 | 100.00 | 100.00 | 100.00 |
| June 27 | 99.89 | 100.00 | 100.00 | 99.94 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| July 4 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

The nature of the shelter in which the weevils are hibernating has a decided influence upon the rate of emergence, as is shown in Table XLIV, based upon the experiments of the Louisiana Crop Pest Commission at Mansura, La., in 1909.

TABLE XLIV.—*Effect of nature of shelter upon rate of emergence of the boll weevil, at Mansura, La., 1909.*

| Character of hibernating quarters. | Dates by which certain percentages of the surviving weevils were out of hibernation. | | | |
|---|---|---|---|---|
| | 25 per cent. | 50 per cent. | 75 per cent. | 100 per cent. |
| Average quarters (cages 5 and 51) | March 19 | April 12 | May 15 | June 27. |
| Open field (cages A and 5) | March 31 | April 29 | May 24 | June 21. |
| Swamp (cages B and 51) | April 8 | May 20 | June 1 | June 29. |
| Moss (cages A and B) | April 13 | do | June 2 | Do. |

It will be noticed that only four cages entered the consideration, cage 5 being average quarters in open field, cage 51 being in average quarters in swamp, cage A being Spanish moss in open field, and cage B being moss in swamp.

## SURVIVAL OF HIBERNATED WEEVILS.

The central idea in all the hibernation experiments has been the determination of the percentages of weevils which survive under different conditions and different treatments. In obtaining the facts which have been discussed in the preceding and following paragraphs on hibernation the grand total of 181,932 weevils has been used. With such a large series it is reasonable to suppose that the average percentage of survival must very nearly approximate the normal. This survival in nine series of experiments conducted in seven years at six localities representing the principal climatic, shelter, and other conditions of the infested region has been 7.6 per cent. Table XLV presents the final summaries of each ot the nine series.

TABLE XLV.—*Summary of survival of the boll weevil in all the more important experiments.*

| Places. | Total number of weevils entering hibernation. | Total number of weevils surviving hibernation. | Percentage of survival. |
|---|---|---|---|
| Keatchie, La., 1906 | 24,700 | 731 | 2.1 |
| Mansura, La., 1909 | 16,281 | 3,260 | 20.0 |
| Mansura, La., 1910 | 22,179 | 1,038 | 4.6 |
| Tallulah, La., 1910 | 21,835 | 317 | 1.4 |
| Tallulah, La., 1911 | 8,439 | 46 | .5 |
| Five Louisiana series | 93,331 | 5,392 | 5.7 |
| Dallas, Tex., 1907 | 32,439 | 3,464 | 10.6 |
| Calvert, Tex., 1907 | 20,430 | 1,834 | 8.9 |
| Victoria, Tex., 1907 | 23,645 | 3,026 | 12.8 |
| Dallas, Tex., 1908 | 12,087 | 118 | .9 |
| Four Texas series | 88,601 | 8,442 | 9.5 |
| Total of nine series | 181,932 | 13,834 | 7.6 |

The highest average percentage of survival for any locality is 20 per cent, at Mansura, La., in 1909, and the lowest average is 0.5 per cent, at Tallulah, La., in 1911. The highest percentage of survival in any cage was 47.72 per cent of 767 weevils, at Mansura, in a cage with average conditions established December 14, 1908. The lowest percentage of survival is no weevils, from 408, at Tallulah, in two cages with average conditions, established November 15, 1910.

## RELATION OF FALL DESTRUCTION TO SURVIVAL.

One of the most important recommendations for boll-weevil control is that of early destruction of the cotton stalks. It has long been known that the earlier the stalks are destroyed the less chance the weevils have of surviving. Table XLVI, showing the percentage of emergence by dates of installation, affords an incontrovertible argument in support of this recommendation.

TABLE XLVI.—*Percentage of emergence of the boll weevil, by dates of installation.*

| Place. | Sept. 16–30. | Oct. 1–15. | Oct. 16–31. | Nov. 1–15. | Nov. 16–30. | Dec. 1–15. | Dec. 16–31. |
|---|---|---|---|---|---|---|---|
| *Texas points.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Dallas, 1907 | | 2.61 | 6.67 | 20.57 | 4.36 | | |
| Calvert, 1907 | | 3.15 | 3.98 | 10.33 | 2.65 | | |
| Victoria, 1907 | | | 6.17 | 17.69 | 16.22 | | |
| Dallas, 1908 | 0.23 | .39 | 2.8 | 1.68 | 5.26 | | |
| Texas, weighted average percentage | .23 | 2.33 | 5.62 | 15.42 | 16.05 | | |
| Total weevils installed | 5,213 | 7,729 | 27,806 | 30,431 | 12,173 | | |
| *Louisiana points.* | | | | | | | |
| Keatchie, 1906 | | | | | 2.71 | 3.23 | 0.8 |
| Mansura, 1909 | 2.7 | 3.31 | 23.9 | 23.8 | 24.56 | 43.23 | 37.06 |
| Mansura, 1910 | .23 | 1.31 | 6.58 | 9.95 | 6.31 | 6.79 | |
| Tallulah, 1910 | .34 | 2.23 | 1.16 | 1.53 | 2.4 | .00 | |
| Tallulah, 1911 | | 1.15 | .54 | .00 | | .00 | |
| Louisiana, weighted average percentage | .37 | 2.00 | 8.04 | 8.82 | 6.07 | 10.65 | 12.61 |
| Total weevils installed | 8,186 | 14,218 | 24,464 | 9,620 | 24,252 | 10,208 | 1,483 |
| Grand weighted average percentage | 0.31 | 2.07 | 6.58 | 14.26 | 9.00 | 10.65 | 12.61 |
| Total weevils installed | 13,399 | 21,947 | 52,270 | 40,051 | 36,425 | 10,208 | 1,483 |

Converted into terms of the number of weevils in every thousand which would survive the winter if stalks were destroyed on a given date, we can see the force of Table XLVI. It is even more evident from the arrangement of the data given below in Table XLVII.

TABLE XLVII.—*Number of boll weevils in each 1,000 which would have survived destruction of stalks on a given date.*

| Date of destruction. | In Texas. | In Louisiana. |
|---|---|---|
| September 16-30 | 2 | 3 |
| October 1-15 | 23 | 20 |
| October 16-31 | 56 | 80 |
| November 1-15 | 154 | 88 |
| November 16-30 | 160 | 60 |
| December 1-15 | (?) | 106 |
| December 16-31 | (?) | 126 |

## RELATION OF SHELTER TO SURVIVAL.

It has already been stated that the density of the shelter has a bearing upon the survival. This is best shown by the following records (Table XLVIII):

TABLE XLVIII.—*Relation of shelter of boll weevils to their survival.*

| Place. | Date installed. | Weevils. | Shelter. | Survival. |
|---|---|---|---|---|
| | | | | *Per cent.* |
| Mansura, La | October 26 | 2,436 | Average | 20.00 |
| Do | do | 2,158 | Moss | 37.76 |
| Victoria, Tex | October 28 | 2,375 | Average | 5.61 |
| Do | November 6 | 2,850 | Moss | 23.65 |
| Do | November 10 | 2,850 | Average | 12.70 |

## RELATION OF CLIMATE TO SURVIVAL.

Another important consideration in determining the causes for high or low survival is the climate. Some of the principal relationships are brought out in Table XLIX below:

TABLE XLIX.—*Relation of climate to survival of boll weevils in hibernation.*

| Place and year. | Description. | Number of weevils. | Per cent of survival. | Periods of emergence. | Rainfall and temperature, Oct. 1-Mar. 15. Rainfall. | Absolute minimum. | Total degrees below 32. |
|---|---|---|---|---|---|---|---|
| | | | | | *Inches.* | °*F.* | °*F.* |
| Tallulah, La., 1910-11. | 10 cages, variety of shelter, installed Oct. 15-Dec. 1. | 8,439 | 0.5 | Feb. 15-June 4 | 8.30 | 9.5 | 199.5 |
| Dallas, Tex., 1907-8. | 9 cages, variety of shelter, Sept. 21-Nov. 18. | 12,087 | .9 | Feb. 19-June 16 | 22.61 | 15.0 | 233.0 |
| Tallulah, La., 1909-10. | 19 cages, great variety of shelter, Sept. 16-Dec. 14. | 21,835 | 1.4 | Feb. 15-June 27 | 19.34 | 13.0 | 378.5 |

TABLE XLIX.—*Relation of climate to survival of boll weevils in hibernation*—Con.

| Place and year. | Description. | Number of weevils. | Per cent of survival. | Periods of emergence. | Rainfall and temperature, Oct. 1-Mar. 15. Rainfall. | Absolute minimum. | Total degrees below 32. |
|---|---|---|---|---|---|---|---|
| | | | | | *Inches.* | °*F.* | °*F.* |
| Keatchie, La., 1905-6. | 18 cages, variety of shelter (1 bare), installed Nov. 18-Dec. 18. | 24,700 | 2.1 | Mar. 22-June 28.. | 18.87 | 21.0 | 91.0 |
| Mansura, Tex., 1909-10. | 19 cages, great variety of shelter, Sept. 16-Dec. 14. | 22,179 | 4.6 | Feb. 15-June 15.. | 15.37 | 19.5 | 151.5 |
| Calvert, Tex., 1906-7. | 10 cages, variety of shelter, Oct. 1-Dec. 10. | 19,408 | 8.9 | Mar. 4-July 1.... | 11.87 | 26.0 | 47.0 |
| Dallas, Tex., 1906-7. | 10 cages, variety of shelter, Oct. 13-Dec. 6. | 30,864 | 10.6 | Mar. 1-June 19... | 8.52 | 22.0 | 145.0 |
| Victoria, Tex., 1906-7. | 10 cages, variety of shelter, Oct. 25-Nov. 29. | 22,463 | 12.8 | Feb. 28-June 15.. | 11.25 | 27.0 | 5.0 |
| Mansura, La., 1908-9. | 19 cages, great variety of shelter, Sept. 28-Dec. 21. | 16,281 | 20.0 | Feb. 21-June 29.. | 10.44 | 23.0 | 81.0 |

One of the most striking features of Table XLIX is the disparity between the percentage of survival through the six winters considered. A special effort has been made to discover the factors that cause this disparity. Among those that have been considered are the absolute minimum temperature, the daily accumulated degrees below 32 during the hibernation season, the number of times a temperature below 32° was reached, and the rainfall. Contrary to our expectations, it appears that the number of times the temperature descends below 32° has no direct effect. However, there seems to be a direct relation between the absolute minimum temperature and the rainfall, taken together, and the percentage of survival. As the absolute minimum ascends and the rainfall decreases the survival seems to increase. The greatest survival (Mansura, La., 1908-9) was accompanied by the third highest minimum temperature and the third lowest rainfall during the hibernation season. In the same way the next to the highest survival (Victoria, Tex., 1906-7) was accompanied by the highest absolute minimum temperature and the fourth lowest rainfall. Conversely, the lowest survival (Tallulah, La., 1910-11) was accompanied by the lowest absolute minimum temperature and the lowest rainfall. The next to the lowest survival (Dallas, Tex., 1907-8) was accompanied by the third lowest absolute minimum temperature and the highest rainfall. It thus appears that a moderately cold winter, with temperature frequently near the zone of fatal temperatures and excessive precipitation, is very unfavorable for the weevil, but a winter with little precipitation and a temperature within the zone of fatal temperatures is by far the most fatal. Conversely, a winter with temperatures always above 20° and moderate precipitation is the most favorable for the weevil.

Certain climatic phenomena are likely to occur which will emphasize still more the effects produced by extreme cold and great precipitation. At Tallulah, La., in 1910–11, the early freeze on October 29 cut off the food supply and was followed by warm temperatures in November which required feeding. The minimum experienced in January completed the control and was low enough to counteract the small precipitation.

## LONGEVITY OF HIBERNATED WEEVILS.

From the beginning of the hibernation experiments in 1905 it has been the custom to place the emerging weevils in rearing jars or cages to determine the average and maximum longevity with and without food. The data obtained have a bearing upon the proper time for planting and upon other practical points. In these experiments 9,295 weevils have been used, as shown in Table L. The fed weevils were furnished cotton squares as soon as they became available. Before that time they were given fresh cotton leaves daily. The unfed series was supplied with water only. Both series were placed in small cages where general conditions closely approaching those in nature were maintained. It should be especially noted that fed weevils show over double the longevity of unfed weevils throughout the season.

Table L.—*Longevity of hibernated boll weevils after emergence.*

| Place. | Unfed series. | | | Fed series. | | |
|---|---|---|---|---|---|---|
| | Number of weevils. | Longevity. | | Number of weevils. | Longevity. | |
| | | Maximum. | Average. | | Maximum. | Average. |
| | | *Days.* | *Days.* | | *Days.* | *Days.* |
| Keatchie, La., 1906 | 412 | 62 | 17.11 | ........ | ........ | ........ |
| Dallas, Tex., 1907 | 2,179 | 90 | 12.50 | 901 | 130 | 38.20 |
| Calvert, Tex., 1907 | 1,079 | 48 | 8.07 | 715 | 118 | 30.00 |
| Victoria, Tex., 1907 | 1,360 | 44 | 8.20 | 1,349 | 86 | 14.70 |
| Mansura, La., 1909 | 261 | 44 | 11.09 | 360 | 36 | 10.42 |
| Natchez, Miss., 1909 | 4 | 19 | 8.75 | 36 | 25 | 12.20 |
| Mansura, La., 1910 | 175 | 28 | 8.78 | 146 | 81 | 36.50 |
| Tallulah, La., 1910 | 179 | 21 | 5.70 | 121 | 105 | 22.30 |
| Tallulah, La., 1911 | 8 | 12 | 7.25 | 10 | 25 | 13.30 |
| Total | 5,657 | ........ | ........ | 3,638 | ........ | ........ |
| Maximum | ........ | 90 | 17.11 | ........ | 130 | 38.20 |
| Weighted average | ........ | ........ | 10.55 | ........ | ........ | 24.20 |

It will be noted that the records of longevity of weevils after emergence from hibernation referred to above are based upon specimens that had passed the winter in artificial hibernation cages. However, a number of observations have been made upon the longevity of weevils which pass the winter under natural conditions in the field. For instance, March 1, 1906, a number of weevils were collected from cotton bolls at Brenham, Tex. These were placed in small cages and observed daily. The last one died on May 31. Naturally the time this weevil was deprived of food the preceding fall is not known, but it must have been prior to December 1, as the frosts had

killed all cotton at Brenham by that date. Assuming that it entered hibernation on December 1, it lived six months without food. In another case weevils collected in the field in the spring at Calvert, Tex., lived without food as late as June 8. This gives a duration of life without food of six months and twelve days. Similar observations indicate clearly that the longevity of weevils that pass the winter in artificial cages is a proper index to the longevity of those which pass the winter in the field.

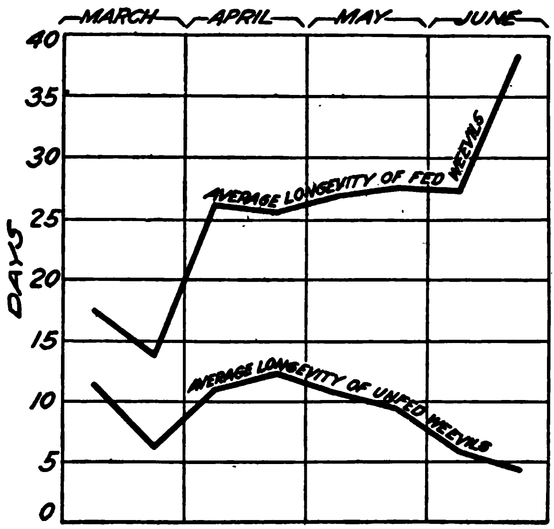



FIG. 25.—Diagram illustrating average longevity of boll weevils after emerging on a given date. (Original.)

It has become quite apparent from a study of the records that the longevity of weevils provided with food is considerably greater with weevils emerging in June than with those emerging in March, while, on the contrary, with unfed weevils the longevity decreases with the lateness of emergence. (Table LI.)

The diagram (fig. 25) illustrates the above statement graphically.

TABLE LI.—*Latest dates of death of hibernated boll weevils.*

| Time of emergence. | Unfed weevils. | | Weevils fed foliage. | | Weevils fed squares. | |
|---|---|---|---|---|---|---|
| | Mansura, La., 1910. | Tallulah, La., 1910. | Mansura, La., 1910. | Tallulah, La., 1910. | Mansura, La., 1910. | Tallulah, La., 1910. |
| Feb. 15-28 | Mar. 18 | ........ | ........ | ........ | ........ | ........ |
| Mar. 1-15 | Apr. 13 | Apr. 1 | ........ | ........ | ........ | ........ |
| Mar. 16-31 | Apr. 20 | Apr. 12 | June 20 | ........ | ........ | ........ |
| Apr. 1-15 | Apr. 28 | Apr. 28 | July 5 | June 21 | ........ | ........ |
| Apr. 16-30 | May 13 | May 21 | June 28 | June 18 | ........ | ........ |
| May 1-15 | May 29 | June 1 | July 15 | July 15 | ........ | ........ |
| May 16-30 | June 12 | June 15 | July 12 | July 26 | ........ | Sept. 13 |
| June 1-15 | ........ | June 27 | July 29 | July 7 | July 19 | July 1 |
| June 15-30 | ........ | ........ | ........ | ........ | ........ | Aug. 31 |
| Entire season | June 12 | June 27 | July 29 | July 26 | July 19 | Sept. 13 |

## MAXIMUM LENGTH OF LIFE.

In connection with Table LI it will be noticed that the latest known recorded death of a hibernated weevil is September 13. This fact, taken in conjunction with Table LII, showing the maximum longevity

of weevils from the time of entering hibernation to death, is of great interest. The maximum longevity of 335 days, or 11 months, gives proof of the wonderful vitality of the boll weevil.

TABLE LII.—*Longevity of hibernated boll weevils from installation to death.*

| Place. | Condition. | Longevity. | |
|---|---|---|---|
| | | Average. | Maximum. |
| | | *Days.* | *Days.* |
| Mansura, La., 1910 | Unfed | 158 | 226 |
| Tallulah, La., 1910 | ....do | 169 | 243 |
| Mansura, La., 1910 | Fed foliage | 206 | 256 |
| Tallulah, La., 1910 | ....do | 221 | 272 |
| Mansura, La., 1910 | Fed squares | 257 | 267 |
| Tallulah, La., 1910 | ....do | 262 | 335 |

## RELATION OF EMERGENCE AND LONGEVITY TO TIME OF PLANTING.

The data that have been presented show the extreme importance of early planting as a means of averting damage by the boll weevil. Early planting takes advantage of the portion of the season when the weevils are present in the fields in smallest numbers. The longer planting is deferred the greater the number of weevils which will have emerged. The advantage of an early crop has been shown in many experiments by the Bureau of Entomology and by practical cotton planters. On the other hand, the experience in late plantings has been disastrous. The obvious explanation is in the prolonged period of emergence and the remarkable ability of the weevils to live without food after emergence. This topic will receive additional treatment under the heading of "Repression."

## NATURE OF WEEVIL ACTIVITY FOLLOWING EMERGENCE FROM HIBERNATION.

In the section dealing with the spring movement we have discussed the early search of the weevils for food. There are certain points connected with the spring movements, however, which are intimately related to hibernation, and these will be dealt with here.

[1] In following the activity of emerged weevils at Dallas, Tex., certain specimens were marked in such a way as to make it possible to recognize them individually, and the weevils were allowed to remain practically undisturbed in the section where they had spent the winter. In making the daily examinations record was kept of the appearance or disappearance of each individual weevil. No food was supplied in any of the sections until toward the close of the experiments in May, when seed was planted and cotton began growing before the last weevils emerged. A majority of the weevils were seen a second time, and some disappeared and reappeared as many as eight times. The longest period between the first and second appearance of any individual was 43 days.

[1] From Bull. 77, Bureau of Entomology, pp. 50, 51.

TABLE LIII.—*Intermittent activity of unfed boll weevils after emergence, at Dallas, Tex., 1906.*

| Number of weevils seen— | | | | | | | | Weevils "rehibernated"— | | | | | | Average survival, number of days. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Once. | | Twice. | | Three times. | | |
| Once. | Twice. | Three times. | Four times. | Five times. | Six times. | Seven times. | Eight times. | Number. | Days. | Number. | Days. | Number. | Days. | |
| 46 | 26 | 15 | 11 | 6 | 2 | 2 | 1 | 17 | 8.7 | 6 | 7.2 | 2 | 3.5 | 6.8 |

The observations recorded in Table LIII show conclusively that weevils may leave their winter quarters during warm days and, failing to find food, they may again become quiet and emerge again after a considerable interval. This fact has an important bearing upon the proposition which is frequently advanced by planters of starving the weevils in the spring by deferring the time of planting. While many weevils might perish in this way, it is certain that many more would be able to survive and reappear at intervals, so that there would be plenty of weevils to infest the crop, even though this might be planted as late as is possible to secure any yield.

Other observations were made upon the intermittent activity of unfed weevils during the spring of 1906. Weevils from Calvert, Victoria, and Brenham, Tex., were tested. The weevils from Calvert and Victoria had been confined in hibernation cages throughout the winter. Those from Brenham were collected in the field early in March. None of these weevils had tasted food after emergence. The results are shown in Table LIV. In this table the date of death, unless otherwise indicated, is considered as having been the middle date between the last examination at which a weevil was found alive and that at which it was found dead.

TABLE LIV.—*Intermittent activity of unfed emerged boll weevils, 1906.*[1]

| Locality. | When collected. | When put in hibernation. | When removed from hibernation. | When rehibernated. | Weevils put in rehibernation. | Date of first examination. |
|---|---|---|---|---|---|---|
| | 1905 | 1905 | 1906 | 1906 | | |
| Calvert, Tex. | Nov. 25 | Nov. 27 | Apr. 19 | Apr. 23 | 20 | May 10 |
| Victoria, Tex. | Nov 7, 13; Dec. 11 | Nov. 7, 13; Dec. 11 | Apr. 6 | Apr. 16 | 7 | Apr. 24 |
| | 1906 | | | | | |
| Brenham, Tex. | Nov. 1 | ........... | Mar. 1 | Mar. 7 | 8 | May 11 |

| Locality. | Weevils surviving. | Date of second examination. | Weevils surviving. | Date of third examination. | Weevils surviving. | Date of death of longest survival. | Average length of life in rehibernation. |
|---|---|---|---|---|---|---|---|
| | | | | | | | *Days.* |
| Calvert, Tex. | 10 | May 22 | 6 | June 8 | 0 | June 8 | 30.4 |
| Victoria, Tex. | 3 | May 10 | 0 | .......... | .......... | May 10 | 19.1 |
| Brenham, Tex. | 2 | May 23 | 1 | May 31 | 0 | May 31 | 67.4 |

[1] From Bulletin 77, Bureau of Entomology, p. 52.

The records for Calvert and Brenham show a very remarkable power of endurance in some weevils, the average survival for the two lots of 20 and 8 weevils being over 30 and 60 days, respectively.

## NATURAL CONTROL.

Considerable attention has been given to the study of the natural forces which control the boll weevil. These studies have revealed a large amount of important data, some of which have been used in several bulletins. In the present publication it is possible to give only a summary of the most important results.

In general, the natural agencies which control the boll weevil may be classified as climatic (consisting principally of heat which kills directly and also indirectly by rendering the food supply unsuitable, and dryness, the effects of which are intermingled with those of heat), plant resistance, parasites and other insect enemies, diseases, and birds. Each of these agencies will be discussed separately, but a general summarization may be of value. Table LV is a summary of the observations made in the years 1906 to 1909 on weevil stages from many localities. It deals with the mortality of immature stages from all causes exclusive of plant proliferation.

TABLE LV.—*Annual mortality of immature boll weevils in all classes of cotton forms. 1906–1909.*

| Year. | Total forms examined. | Total stages found. | Total stages dead. | Number stages killed by— | | | Percentages of mortality due to— | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Climate. | Predators. | Parasites. | All causes. | Climate. | Predators. | Parasites. |
| 1906 | 100,644 | 40,073 | 22,353 | 10,078 | 10,547 | 1,728 | 55.81 | 25.15 | 26.31 | 4.31 |
| 1907 | 21,980 | 13,405 | 7,275 | 3,896 | 2,263 | 1,116 | 54.27 | 29.06 | 16.88 | 8.32 |
| 1908 | 72,234 | 29,546 | 13,103 | 6,268 | 3,878 | 2,957 | 44.34 | 21.21 | 13.12 | 10.00 |
| 1909 | 27,857 | 11,653 | 4,863 | 3,012 | 1,231 | 620 | 41.73 | 25.84 | 10.56 | 5.32 |
| 1906–1909 | 222,715 | 94,677 | 47,594 | 23,254 | 17,919 | 6,421 | 50.26 | 24.56 | 18.92 | 6.78 |

Inasmuch as the material used in making the examinations was derived from many sources and in different proportions each year, a system of weighting the different kinds of material was devised. Table LVI presents a summarization of this weighting in terms of percentages of mortality:

TABLE LVI.—*Weighted average mortality of the boll weevil, 1906–1909, due to various causes.*

| Year. | Proliferation.[1] | Climate. | Predation. | Parasitism. | Total. |
|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 1906 | 12.42 | 24.39 | 24.85 | 2.94 | 64.61 |
| 1907 | 12.42 | 28.16 | 16.18 | 3.83 | 60.61 |
| 1908 | 12.42 | 17.83 | 11.77 | 6.34 | 48.37 |
| 1909 | 12.42 | 23.01 | 10.92 | 2.63 | 48.99 |
| 1906–1909 | 12.42 | 24.45 | 15.93 | 3.93 | 56.73 |

[1] The average determined in 1906 (see Bull. 59, Bureau of Entomology) is used to apply to other years.

The extensive series of examinations tabulated above (Table LVI) were made upon immature weevils in all conditions of squares and bolls, the principal of which are known as hanging dry squares, fallen squares, hanging dry bolls, and fallen bolls. The conditions in these four classes of material vary greatly as does the mortality, as is shown in Table LVII. The apparent discrepancy between the totals in Table LVII and in Table LVI is due to the admission of other minor classes of material in the first table. This table (LVII) also excludes mortality from plant proliferation.

TABLE LVII.—*Mortality of immature boll weevils in various classes of cotton forms, 1906–1909.*

| Class of infested forms. | Total forms examined. | Total stages found. | Total stages dead. | Number stages killed by— | | | Percentages of mortality due to— | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Climate. | Predators. | Parasites. | All causes. | Climate. | Predators. | Parasites. |
| Fallen squares | 107,293 | 63,985 | 34,403 | 17,596 | 13,958 | 2,849 | 53.76 | 27.50 | 21.81 | 4.45 |
| Hanging squares | 24,683 | 14,390 | 7,084 | 2,543 | 1,745 | 2,796 | 49.22 | 17.67 | 12.19 | 19.43 |
| Hanging bolls | 41,738 | 8,737 | 3,328 | 1,709 | 1,054 | 565 | 38.09 | 19.56 | 12.06 | 6.47 |
| Fallen bolls | 46,200 | 6,825 | 2,375 | 1,128 | 1,148 | 99 | 34.79 | 16.52 | 16.80 | 1.45 |
| All classes | 219,914 | 93,937 | 47,190 | 22,976 | 17,905 | 6,309 | 50.23 | 24.45 | 19.06 | 6.71 |

Still another extremely important aspect of this large series needs to be shown. This is the geographical differences in the control by climate, predators, and parasites.

TABLE LVIII.—*Average mortality of immature boll weevils in various classes of cotton forms by States, 1906–1909.*

| Class of forms and State. | Total forms examined. | Total stages found. | Total stages dead. | Stages killed by— | | | Mortality due to— | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Climate. | Predators. | Parasites. | All causes. | Climate. | Predators. | Parasites. |
| *Fallen squares.* | | | | | | | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| Arkansas | 374 | 162 | 62 | 43 | 17 | 2 | 38.27 | 26.54 | 10.49 | 1.23 |
| Louisiana | 28,204 | 15,177 | 4,895 | 1,990 | 2,243 | 562 | 32.25 | 13.11 | 14.77 | 3.70 |
| Mississippi | 4,216 | 2,661 | 1,070 | 416 | 263 | 391 | 40.21 | 15.63 | 9.88 | 14.69 |
| Oklahoma | 657 | 442 | 238 | 100 | 117 | 21 | 53.84 | 22.62 | 26.47 | 4.75 |
| Southwest Texas | 2,757 | 1,390 | 390 | 186 | 152 | 52 | 28.06 | 13.38 | 10.93 | 3.74 |
| Southern Texas | 38,007 | 25,063 | 16,965 | 8,547 | 7,377 | 1,041 | 67.68 | 34.10 | 29.43 | 4.15 |
| East Texas | 825 | 464 | 248 | 136 | 107 | 5 | 53.44 | 29.31 | 23.06 | 1.07 |
| Central Texas | 14,879 | 7,628 | 4,233 | 2,386 | 1,602 | 245 | 55.49 | 31.28 | 21.00 | 3.21 |
| Northeast Texas | 10,318 | 6,497 | 3,439 | 1,812 | 1,347 | 280 | 52.93 | 27.89 | 20.73 | 4.30 |
| North-Central Texas | 7,066 | 4,501 | 2,863 | 1,980 | 633 | 250 | 63.60 | 43.99 | 14.06 | 5.55 |
| *Hanging squares.* | | | | | | | | | | |
| Arkansas | 1,612 | 1,144 | 494 | 188 | 60 | 246 | 43.18 | 16.43 | 5.24 | 21.50 |
| Louisiana | 8,601 | 5,184 | 2,182 | 881 | 651 | 650 | 42.09 | 16.99 | 12.55 | 12.53 |
| Mississippi | 784 | 499 | 182 | 41 | 34 | 107 | 36.47 | 8.21 | 6.81 | 21.44 |
| Oklahoma | 100 | 63 | 26 | 6 | 0 | 20 | 41.27 | 9.53 | 0.00 | 31.74 |
| Southwest Texas | 89 | 46 | 24 | 6 | 2 | 16 | 52.10 | 13.00 | 4.30 | 34.70 |
| Southern Texas | 5,740 | 3,626 | 1,937 | 727 | 496 | 714 | 53.41 | 20.04 | 13.67 | 19.69 |
| East Texas | 192 | 135 | 10 | 5 | 1 | 4 | 7.40 | 3.70 | 0.74 | 2.96 |
| Central Texas | 2,094 | 1,052 | 703 | 253 | 208 | 242 | 66.82 | 24.04 | 19.75 | 22.98 |
| Northeast Texas | 4,044 | 1,667 | 887 | 290 | 211 | 386 | 53.80 | 17.39 | 12.66 | 23.15 |
| North-Central Texas | 1,992 | 1,141 | 766 | 196 | 88 | 492 | 67.13 | 17.17 | 7.71 | 43.12 |

Although the grand total of the examinations shows a higher mortality due to fallen squares than to hanging squares, it is noticeable that the mortality in hanging squares is greater in Arkansas, Louisiana, southwestern, central, northeastern, and north-central Texas, and less in Mississippi, Oklahoma, and southern and eastern Texas.

As shown in Table LVIII, the highest mortality in fallen squares is 67.68 per cent in southern Texas and the lowest 28.06 per cent in southwestern Texas. In hanging squares the highest mortality is 67.13 per cent in north-central Texas and the lowest, 7.40 per cent, in eastern Texas.

Climatic control is highest in fallen squares in north-central Texas, at 43.99 per cent, and lowest in Louisiana, at 13.11 per cent, while in hanging squares it reaches 24.04 per cent only in central Texas and is as low as 3.70 per cent in eastern Texas.

Predatory control in fallen squares is highest in southern Texas, at 27.43 per cent, and lowest in Mississippi, at 9.88 per cent, while in hanging squares its highest average is 19.75 per cent in central Texas and its lowest no per cent in Oklahoma.

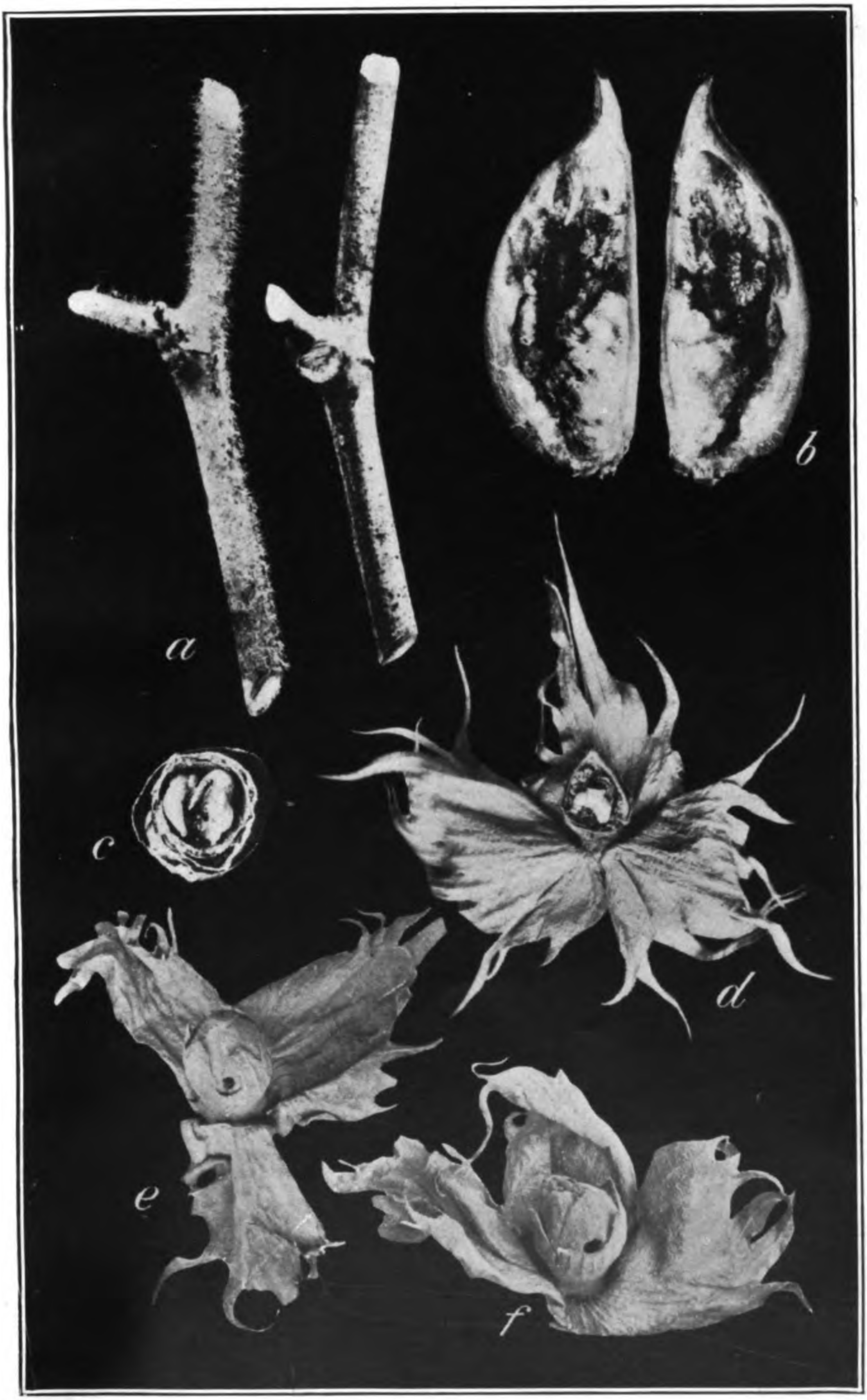
Parasitic control in fallen squares is highest in Mississippi, at 14.69 per cent, and lowest in eastern Texas, at 1.07 per cent. On the other hand, in hanging squares it is highest in north-central Texas, with 43.12 per cent, and lowest in eastern Texas, with 2.96 per cent.

In fallen squares it is generally the case that over half of the mortality is due to climate, but in Louisiana, Mississippi, Oklahoma, and southwestern Texas insect control is greater than climatic. In hanging squares the insect control is invariably greater than climatic control, and in Mississippi, Oklahoma, and southwestern and north-central Texas parasitic control alone is greater than the climatic plus the predatory control. It was shown in the table comparing the total mortality in all classes of forms (Table LVII) that the weighted average mortality due to insects was 25.77 per cent, as against 24.45 per cent due to climate. All of this evidence is cited to show that in reality the insect enemies produce a very large proportion of the mortality of the boll weevil and should therefore be encouraged in every way possible. Of course, it is evident that climatic control is even superior, because of the influences it brings to bear upon every phase of the weevil's existence.

Regional comparisons such as have been made above are of the greatest importance in determining what factors in natural control need to be given the greatest encouragement by cultural expedients or otherwise.

## CLIMATIC CONTROL.

From almost every viewpoint the climatic control of the boll weevil is the most important which this insect experiences. The weevil reacts to a multitude of conditions of temperature and humidity. The time of entrance into hibernation, the length of the hibernation period, the time of emergence from hibernation, the length of the various immature stages, the rate of oviposition, and even the proportion of sexes are profoundly affected by these agencies. In many cases their effects are not direct. They may affect the weevil indirectly through the cotton plant. For example, drought may interfere with the fruiting of the cotton plant and thus deprive the weevils of food.




NATURAL CONTROL OF THE BOLL WEEVIL.

*a*, Pilose and nonpilose stems of cotton; *b*, larva of boll weevil crushed by proliferation; *c*, pupa of *Catolaccus incertus* on pupa of cotton boll weevil; *d*, larva of *Microbracon mellitor* attacking boll-weevil larva; *e*, *f*, holes gnawed by *Solenopsis geminata* in effecting entrance into infested squares. (Original.)

The most conspicuous illustration of the climatic control of the weevil lies in the failure of the pest to establish itself in the drier portions of Texas. For several years multitudes of weevils have flown from the more humid portions of Texas to the west, where the climate is drier. In fact, every year there has been a large inflow of weevils into this region. Every season, however, the conditions have practically immediately prevented the establishment of the weevil. The most important factor has been dryness, but there are others that must be considered. Among them is the fact that there is comparatively little winter protection for the insect. In addition, an indirect result of small precipitations is the growth of cotton plants of only small size. This results in a small amount of shade and thus augments the direct effect of heat and dryness upon the infested squares which fall to the ground.

Frequently the effects of climate act upon the enemies of the boll weevil. This is the case where heat destroys the weevils and their parasites in squares that fall to the ground. In several cases, however, heat increases the effectiveness of the enemies of the weevil. A striking example of this was observed on September 2, 1911, by Mr. J. D. Mitchell, of the Bureau of Entomology. A succession of days in which the temperature was very high and the air exceedingly dry caused the premature opening of many cotton bolls in the vicinity of Victoria, Tex. Prior to this time the weevils had destroyed practically all of the squares, and many immature stages were to be found in the bolls thus forced open. In such instances the exposed immature stages of the weevil were subjected to two important destructive agencies. Heat killed many that became exposed to the air, and the ants were able to reach not only those that were exposed, but others inside of the partially opened bolls. If the bolls had not opened, such weevils would have been beyond the reach of the ants. As it was, the climatic conditions not only directly destroyed large numbers of weevils in a situation where climatic factors rarely affect them, but also greatly increased the effectiveness of another unrelated factor of control.

### CLIMATIC INFLUENCES ON VITALITY AND ACTIVITIES.

In the preceding pages numerous effects of climate upon the development and activities of the boll weevil have been pointed out, but these must be summarized in order to show how intimately connected the climate is with every phase of the weevil's life. It appears that the movements of the weevil are sluggish or active in accordance with the nature of the day, cloudy days or low temperatures always causing them to be more sluggish. The number of feeding punctures per square decreases with increases in temperature, and the time before falling of a punctured square also decreases with higher temperatures. In like manner the length of life of the weevil decreases. The age of beginning copulation and the age of beginning oviposition are both increased by decreases in temperature. The activity in oviposition, which is found to begin at 75° F., is greatest in the hottest time of the day, cloudy days causing the oviposition to be less active. The number of eggs per day increases with the temperature and varies for any given temperature with the humidity. The entire period of development increases as the temperature and atmospheric humidity decrease.

The number of generations decreases with the mean temperature and mean humidity.

Hibernation seems to begin at mean temperatures between 56° F. and 60° F., but is hastened by high humidity. Cold nights followed by warm, still days seem to stimulate the weevils to considerable activity in the fall, evidently warning them to seek hibernation quarters. The period of entrance into hibernation is much more rapid as the mean humidity and mean temperature become lower. The emergence of the weevil is in like manner influenced by the temperature, but it must be considered that the actual temperature experienced by the weevil is that which affects the emergence. The time of emergence apparently depends upon an accumulation of a certain amount of effective temperature and a certain amount of rainfall, but if more than the necessary temperature accumulates less rainfall will be needed, and vice versa. The majority of weevils emerge at mean temperatures between 64° F. and 78° F. The percentage of survival seems to decrease as the absolute minimum temperature decreases and the rainfall increases.

The foregoing statements are conclusions based in some cases upon more or less fragmentary information, but in other cases they may almost be considered as laws of climatic control.

## FIELD OBSERVATIONS ON MORTALITY DUE TO HEAT AND DRYNESS.

Heat and dryness affect the weevil in a very simple manner. Unless the square remains moist the food supply becomes unsuitable. In other cases the heat itself causes death directly. Therefore, the hotter and drier the ground upon which the infested square falls, the more certain is the death of the weevil.

In the years 1906 to 1909 an exhaustive study was made of the effects of various climatic and other agencies which control the boll weevil. In this work 222,715 cotton forms (including bolls and squares) were collected by agents of the Bureau of Entomology at 65 localities in Texas, 26 in Louisiana, 7 in Oklahoma, 6 in Arkansas, and 6 in Mississippi. Careful laboratory observations were made to determine the mortality due to heat or dryness and to other factors.

By reference to the series of general tables (LV–LVIII) at the beginning of the discussion of natural control it will be noticed that climatic control kills practically one-fourth of the developing stages, the average for the four years in which records were made being 24.56 per cent, which was slightly surpassed by the total insect control. The highest average climatic control was obtained in 1907, being 29.06 per cent, while in 1908 it averaged only 21.21 per cent.

In rearranging the data to ascertain the condition in which the control was greatest we find the following results: Fallen squares, 27.50 per cent; hanging dry bolls, 19.56 per cent; hanging dry squares, 17.67 per cent; and fallen bolls, 16.52 per cent.

The geographical distribution of climatic control is very interesting. In fallen squares the various sections ranked as follows: North-central Texas, 43.99 per cent; southern Texas, 34.10 per cent; central Texas, 31.28 per cent; eastern Texas, 29.31 per cent; northeastern Texas, 27.89 per cent; Arkansas, 26.54 per cent; Oklahoma, 22.62 per cent; Mississippi, 15.63 per cent; southwestern Texas, 13.38 per cent; Louisiana, 13.11 per cent.

In hanging squares we find a somewhat different arrangement of the sections: Central Texas, 24.04 per cent; southern Texas, 20.04 per cent; northeastern Texas, 17.39 per cent; north-central Texas, 17.17 per cent; Louisiana, 16.99 per cent; Arkansas, 16.43 per cent; southwestern Texas, 13 per cent; Oklahoma, 9.53 per cent; Mississippi, 8.21 per cent; and eastern Texas, 3.70 per cent.

In many of the records made during 1906 it became evident that certain cultural practices greatly favored the amount of control by heat and dryness. The wider the rows, the greater the amount of sunlight which strikes the ground. Consequently the fields with wide rows or in which the stand was imperfect showed the greatest mortality. In a similar way, fields in which were varieties with comparatively small amounts of leafage showed greater mortality due to heat and dryness. It did not become apparent, however, from the observations made, that the direction in which the rows ran made any material difference in the mortality.

The difference between the various sections in the mortality in fallen squares is especially conspicuous. This is due undoubtedly primarily to the greater precipitation in the sections with low mortality, which, by keeping the ground more or less moist, prevents such temperatures at the surface as are frequently reached in Texas. The greater rainfall in Louisiana also undoubtedly has an indirect effect. In that State the additional rainfall causes the cotton plants to grow to a large size and to shade the ground more than is the case in Texas, thus preventing the sun from reaching the squares on the ground. The differences in hanging squares are not quite so conspicuous, but are probably due to some extent to atmospheric humidity, density of foliage, and other similar factors.

Equally interesting results were obtained in 1906 with reference to the effect of heat and dryness upon the different stages of the boll weevil. It was found that the mortality in the larval stage amounted to 52 per cent, in the pupal stage to 18 per cent, and in the adult stage to 6 per cent. Nearly 70 per cent of all the mortality caused by heat and dryness occurs, therefore, during the larval stage.

Table LIX illustrates the percentage of stages killed during the warm months of the year by high temperatures and is based upon all of the examinations made during the years 1906 to 1909, inclusive.

TABLE LIX.—*Weighted average heat control of immature stages of the boll weevil, by months, Texas, Louisiana, Oklahoma, Arkansas, and Mississippi.*

| Month. | Forms examined. | Stages found. | Per cent killed by heat and drying. |
|---|---|---|---|
| May | 100 | 56 | 7.20 |
| June | 16,930 | 10,708 | 28.33 |
| July | 43,069 | 21,758 | 25.61 |
| August | 80,923 | 33,170 | 24.62 |
| September | 37,378 | 17,107 | 22.87 |
| October | 17,344 | 8,283 | 16.59 |
| Total | 195,734 | 91,082 | 23.80 |

Many illustrations are available to show the powerful effect of heat and dryness in the reduction in the numbers of boll weevils in cotton fields. The action of this agency is so powerful that it may check the

weevils in a single season so that a crop may be obtained. This was shown in a field which was under observation in Victoria County, Tex., in 1906. It was found in April that a very large number of hibernated weevils appeared in the field. This month was reasonably moist, so that the cotton germinated promptly and made a quick growth. The month of May, however, showed a decided deficiency in precipitation, being more than 3 inches below the normal for the month. This checked the weevil at the time the first infested squares began to drop. The control continued during the month of June, which also showed 3 inches less than the normal rainfall. These conditions resulted in such a checking of the weevils by June that the cotton plants were able to put on a large number of squares. The month of July showed a precipitation above the normal, which caused the plants to grow rapidly. The setback experienced by the weevils, however, during the preceding dry period was so great that they were unable to overtake the production of fruit, so that a yield of about one-fourth of a bale per acre was obtained.

Examples of such complete control within a single season are not common. It frequently happens that a drought continues so long that the plants are seriously affected. In general, however, the plants can recover more rapidly from a drought than the weevil. This results in an advantage to the crop from even a short drought. Of course the advantage becomes greater as the drought is prolonged, provided it is not prolonged to a point where it seriously affects the growth of the plants. Examples of the control of the weevil in one season from heat and dryness of the preceding season are common. Table LX shows a striking instance of this kind. It will be seen that the effects of the drought of 1902 extended into the following season and brought about a marked increase in production. By the following year (1904) the recovery of the weevils from the drought of 1902 was indicated by a decreased production of cotton.

TABLE LX.—*General illustration of drought control of the boll weevil, Nueces County, Tex., 1901–1904.*

| Year. | Rainfall. | | | | Temperature. | | | | Cotton production, Nueces County, equivalent in 500-pound bales. |
|---|---|---|---|---|---|---|---|---|---|
| | Annual. | | Mar. 1–Aug. 31. | | Annual. | | Mar. 1–Aug. 31. | | |
| | Mean average. | Departure from normal. | Mean average. | Departure from normal. | Mean average. | Departure from normal. | Mean average. | Departure from normal. | |
| | *Inches.* | *Inches.* | *Inches.* | *Inches.* | °*F.* | °*F.* | °*F.* | °*F.* | |
| 1901 | 17.49 | −11.90 | 6.74 | − 7.42 | 70.7 | 0.0 | 76.2 | +0.83 | 601 |
| 1902 | 22.22 | − 7.98 | 5.57 | − 7.39 | 71.5 | +1.4 | 77.3 | +1.85 | 480 |
| 1903 | 36.92 | + 6.72 | 25.97 | +11.38 | 69.1 | − .9 | 74.5 | − .9 | 4,099 |
| 1904 | 28.54 | − 1.66 | 13.56 | + .83 | 70.5 | + .4 | 76.0 | + .5 | 1,556 |

## GENERAL DISCUSSION OF THE RELATIONS OF TEMPERATURE TO THE BOLL WEEVIL.

Our studies of the boll weevil lead us to the conclusion that there is a certain degree of temperature above which, under any condition of humidity, no individuals can exist even for a limited time. This point is known as the *maximum fatal temperature*. Below this there is a zone of varying width of temperatures which may be fatal in cases of long exposure or under certain conditions of humidity or insect vitality. This may be known as the *upper zone of fatal temperatures*. Below the zone of fatal temperatures is a zone of temperatures which, when continuing for any length of time, force the insects to shelter. This zone may therefore be fitly called the *zone of æstivation*, and it must be understood that the relative humidity will have a strong influence in moving this zone upward or downward, according to regional conditions. This zone is limited by the point at which effective temperature ceases. Below this point is the *zone of activity*. In this zone will be found the degree of effective temperature, a long continuance of which is necessary to draw the insects out of hibernation. This is not an absolutely fixed point, for it varies with humidity.[1] Possibly the relation could be stated in a definite formula if a sufficient amount of data was available.

The temperature which causes activity is usually known as the *zero of effective temperature*. It is assumed that active metabolism begins at this point and that a certain amount of effective temperatures accumulated in daily units is necessary to bring about a given transformation or function. This sum is known as the *total effective temperature* for any given function. It will vary in accordance with the humidity. Below the zero of effective temperature there will be no necessity of feeding, and locomotion rapidly becomes impossible. On the approach of the zero of effective temperature the insects will display considerable activity in finding winter quarters. We therefore designate the zone below this zero as the *zone of hibernation*. The lower limit of this zone is the highest temperature which may be fatal under certain conditions of humidity or rapid alternation of temperatures. Below this point occurs a more or less restricted *lower zone of fatal temperatures*. The lowest point at which life can exist is known as the *minimum fatal temperature*.

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[1] Of course the manifestation of the absolute temperature which draws the weevils out of hibernation is dependent upon the density of shelter. Certain forms of shelter prevent the weevils from being affected until long after the outside air has been sufficiently warm to cause activity.

These zones are illustrated in the accompanying diagram (fig. 26).

### UPPER ZONE OF FATAL TEMPERATURE.

Numerous experiments have been conducted in dropping adult boll weevils upon the soil at different temperatures to determine the effects upon the insect. In this work 119 tests were made at soil temperatures varying from 110° to 140° F. Below 122° F. none of the weevils were killed, but from 122° F. upward death resulted in times varying from 1 second to 900 seconds. In a general way the exposure necessary to cause death decreased as the temperatures became higher. From these experiments we conclude that the upper zone of fatal temperature for the adult boll weevil may be considered as from 122° to 140° F.

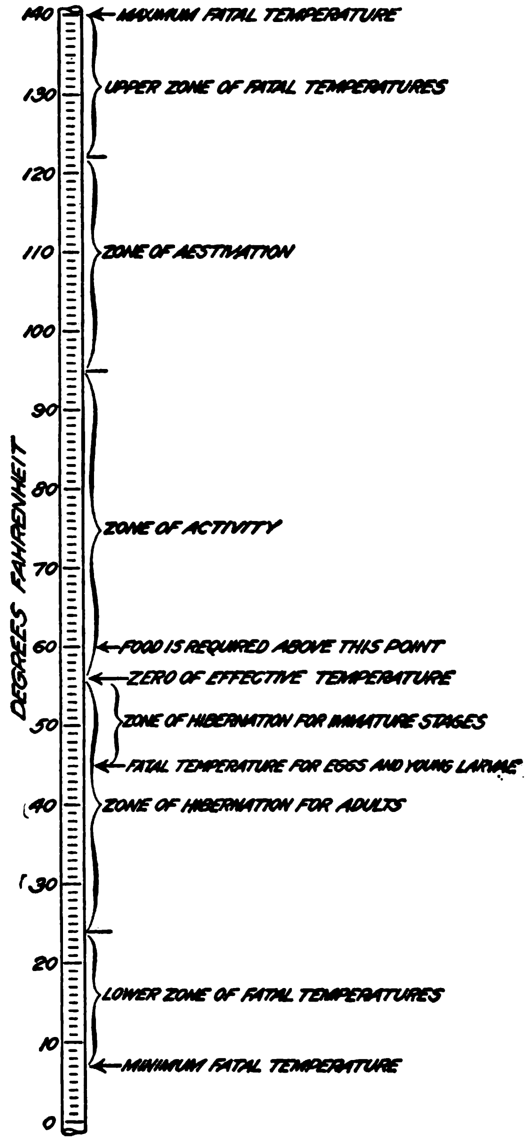


Fig. 26.—Diagram to illustrate the zones of temperature in their relations to the activities of the boll weevil. (Original.)

In the series of experiments to which reference has been made a number of observations were made upon humidity. The atmospheric humidity during the time the experiments were under way, however, was rather constant, ranging from 37 per cent to 40 per cent. Within this narrow range it was not determined that humidity either decreased or increased the length of time necessary to cause the death at any fixed temperature.

It is interesting to note that the zone of fatal temperature for adult weevils which fall to the ground will be reached under general conditions when the temperature recorded at the usual distance above ground at which thermometers are placed reaches 95° F.

### ZONE OF ÆSTIVATION.

During 1906 and 1907, in southern Texas, Mr. J. D. Mitchell observed that many adult weevils were on the ground near the cotton stalks under clods of earth and dead leaves, seeking protection from the intense heat. This indicates a distinct zone of æstivation, although such temperatures may exist only for a few hours at a time. The exact limitations of this zone are undeterminable. Æstivation is a very common habit among weevils. As throwing some light on the probable action of the boll weevil under high temperatures, it is of interest to state that Prof. C. H. T. Townsend, of Piura, Peru, finds that the Peruvian cotton square borer, *Anthonomus vestitus* Boheman, æstivates during the hot months in the fallen squares both as pupa and adult, but remains practically inactive.

### ZONE OF ACTIVITY.

The temperatures at which most of the functions of the boll weevil are exercised lie between the means of 91° F. and 56° F. It is probable, however, that this zone approaches very close to the zone of fatal temperatures. In the spring effective temperature [1] begins to accumulate at approximately 56 degrees, but the total necessary to bring the weevils out of hibernation may be low if the rainfall and humidity for the same period are high, and it must be correspondingly high if the humidity is low.[2] When the two factors have accumulated enough between them they bring about emergence. It is roughly calculated that 172° of effective temperature and 5.1 inches of rain are necessary. A deficiency of effective temperature must be balanced by additional rainfall; a deficiency of rainfall must be balanced by additional effective temperature. For a fuller discussion of this subject see the section on emergence from hibernation (p. 107).

When the weevils have emerged and found food they require a certain number of days of feeding before oviposition can take place. This preoviposition period for hibernating weevils and for the succeeding generations is determined largely by temperature and humidity. As these two factors decrease the period increases. In like manner we have shown on preceding pages how the egg and larval and pupal stages are governed by the same laws. We have also shown that even the daily rate of oviposition is accelerated by increases in temperature and probably also of humidity.

The common impression that "rain brings the weevils" has its basis in the natural increase in the numbers of weevils shortly after a rainy period, due somewhat to the fact that increased humidity reduces the developmental period. A more important factor, however, is that humidity reduces the effects of sunshine in killing the weevil stages.

### ZONE OF HIBERNATION.

The behavior of the weevils in hibernation is fully discussed elsewhere. In ice-box experiments at 45° F. it was found that the weevils would not emerge, but Dr. W. E. Hinds found that 10 weevils which had emerged from hibernation and which were confined 303 weevil

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[1] That is, the temperature at which activity begins.

[2] In a former publication (Bull. No. 51) we adopted the assumption made by other writers that 43° F. is the general zero of effective temperature for insects. Recent experiments have shown conclusively that this is an error, so far as the boll weevil is concerned.

days at 44° to 45° F. made 36 feeding punctures, or at the rate of one puncture every 8.4 days. It is probable that these punctures were all made possible by the removals from refrigeration for examination.

#### LOWER ZONE OF FATAL TEMPERATURES.

In 1904 Dr. W. E. Hinds conducted experiments in the effects of low temperature on eggs and young larvæ. He found that 34 eggs at 45° F. for 13 to 14 days did not hatch when kept later at a temperature of 69° to 70° F. Recently hatched larvæ, however, were killed by nine days' exposure to 45° F.

By experiments conducted with adults in 1905 it was ascertained that 32° F. was not fatal; 24° F. benumbed the weevils, but they could revive; 18° F. killed.

In experiments conducted by Mr. H. P. Wood 32 weevils were exposed to a minimum of 15° F. and an average temperature of 18.6° F. for seven and one-fourth hours and then placed in the refrigerator at a higher temperature, but none recovered.

In similar experiments Mr. W. A. Hooker exposed 11 weevils for six hours to temperatures varying from 15° to 20° F. The weevils were quiet, but later showed signs of life, although they died within two days. Between 7 and 10 degrees, five weevils were killed in six hours. One degree below zero was absolutely fatal.

Observations on the effects of low temperatures upon the weevils in the fields leads to the statement that all places experiencing a temperature under 12° F. in the early part of the winter will profit by an almost complete extinction of the weevil, depending somewhat, of course, upon the amount of protection the weevils may have secured before the freeze. Regions having a normal minimum temperature of zero need have little fear of serious continued depredations from the weevil until the insect has proved itself able to adapt itself to colder temperatures than it is now able to withstand.

In this connection it will be of interest to submit Table LXI, giving the average winter mortality from cold since the beginning of our records.

TABLE LXI.—*Weighted average cold control of immature stages of the boll weevil, by months.*

| Month. | Forms examined. | Stages found. | Killed by cold and wetting. |
|---|---|---|---|
| | | | *Per cent.* |
| January | 5,687 | 1,285 | 36.42 |
| February | 13,597 | 665 | 67.36 |
| March | 2,500 | 159 | 31.44 |
| November | 2,534 | 798 | 41.40 |
| December | 2,663 | 688 | 38.37 |
| Total | 26,981 | 3,595 | 44.61 |

It should be noticed that winter cold is, on the average, almost twice as effective as summer heat.

The history of the boll weevil furnishes several examples of winter control, principal among which are the early freezes of November, 1907, November, 1908, and December, 1909, which greatly reduced weevil damage in large sections.

FATAL VARIATIONS OF TEMPERATURE.

It has long been known that one of the most potent forces in insect control is abnormal variation of temperature. Probably no stronger illustration of such control could be produced than that afforded by the conditions of the winter of 1910–11.

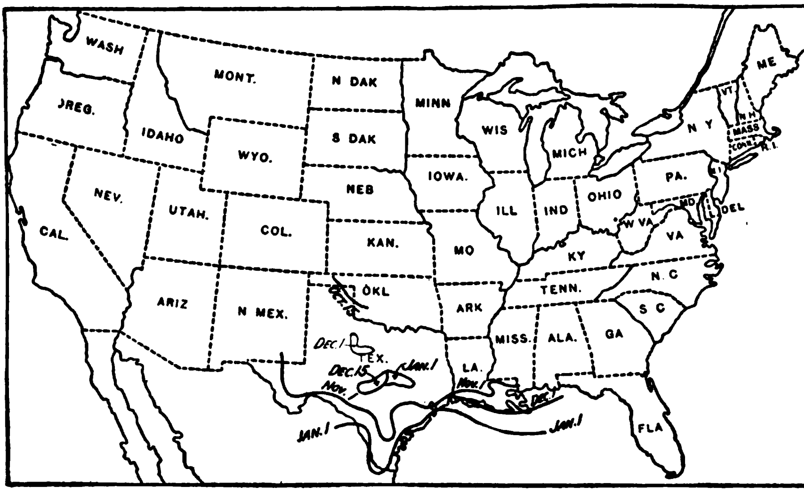



FIG. 27.—Map showing dates of first killing frost in the area infested by the boll weevil, in the winter of 1909–10. (Original.)

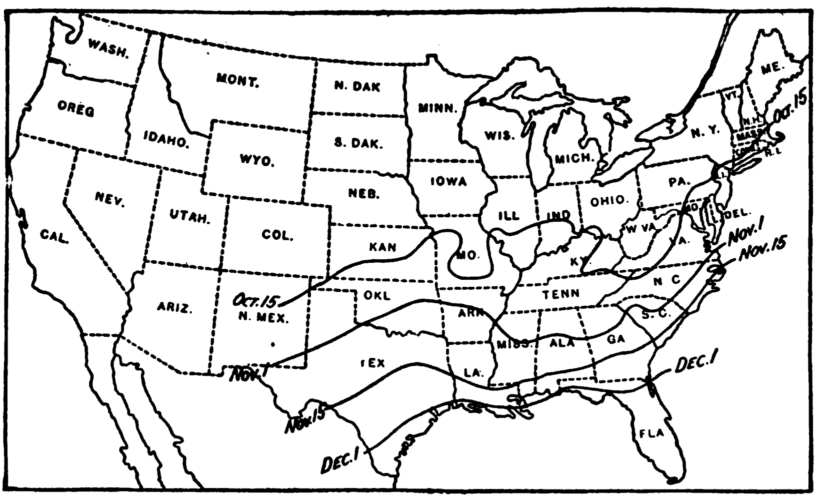



FIG. 28.—Map showing normal dates of first killing frost in the southern United States. (After Weather Bureau Bulletin V.)

On October 29 to 30, 1910, a freeze occurred throughout the cotton belt affecting all but a narrow strip of territory along the Gulf coast and two small interior areas of Texas, as illustrated by the accompanying map (fig. 27). Another map (fig. 28) is presented to show

the normal dates of the first killing frosts. Comparison of these two maps will show at a glance that the first killing freeze of 1910 was over a month earlier than the normal. Such a natural phenomenon is an exact equivalent of artificial fall destruction at the same date. The temperatures were not fatal to the weevils, but were such as to force hibernation and at the same time cut off food supply. If temperatures compelling hibernation had continued, the weevils would have emergep in about the same proportion as would be expected if they were artificially deprived of food on the same date. However, another climatic factor intervened. Almost the entire month of November was warm, and throughout Louisiana, at least, the mean temperature stood at above 56° F. for the month. We have already shown that a continuance of mean temperatures over 56° F. will force the weevils to take food, and that in the absence of food at effective temperatures starvation occurs in a few days. If all of the cotton had been killed by the freeze, the control would have been complete, but there are always sheltered areas on hillsides or near buildings that escape two or three severe freezes, and these areas no doubt harbored many weevils until the cold wave of November 29 drove them to a normal hibernation.


FIG. 29.—Map showing minimum temperatures on October 29 and 30, 1910, the date of the first killing frost in Louisiana. (Original.)

In the map (fig. 29) showing the Louisiana minimum temperatures of October 29 and 30, 1910, on which dates the first killing frost occurred, it will be noticed that no fatal temperature was reached, but that a freezing temperature occurred in practically all of the cotton-producing territory. The other map (fig. 30) illustrates the minimum temperatures of the entire winter of 1910–11 and shows that fatal temperatures (7° F. to 22° F.) occurred throughout the State. These minima


FIG. 30.—Map showing minimum temperatures in the winter of 1910–11 in Louisiana. (Original.)

occurred, however, early in January, at which time all weevils which had survived the starvation of the fall were deeply hidden in hibernation shelters, where sudden changes of temperature have little effect.

The survival from hibernation at Tallulah, La., was only one-half of 1 per cent, as shown in the hibernation statistics, and this, no doubt, must be attributed to the rare combination of early freeze, subsequent long duration of effective temperatures without food, and finally a period of minimum fatal temperatures.

One of the most interesting features of the fall of 1910 in Texas was the presence of two small areas in which the first freeze was delayed from one to two months. (Fig. 27.) We call attention to the most interesting of these cases. The freeze of October 29 was felt in all Texas above the latitude of 31°, except in Erath, part of Comanche, part of Brown, Eastland, Callahan, Taylor, Jones, and Haskell Counties in central-west Texas. In this frost-free area in the following October, 1911, a very heavy infestation was found at Cisco, in Eastland County, and at Brownwood, in Brown County. The infestation diminished in every direction from those places. At Lampasas, 60 miles southeast of Brownwood, where we would naturally expect a much higher infestation than at Cisco, very slight damage occurred, and at Granbury, in Hood County, 60 miles east of Cisco, where the weevils have been present since 1904, they were extremely difficult to find. Thus, it is seen that a territory which had had the weevil much longer than either Brownwood or Cisco had fewer weevils in 1911, because it experienced an earlier killing frost.

## EFFECTS OF FLOODING UPON THE WEEVIL.

Tests at Victoria, Tex., in 1904, were divided into two parts, each of which included both the immature and mature stages. In each part floating and submergence were tested. In the tests made upon the floating power of adults, weevils were isolated and placed in water in tumblers. They were dropped from a considerable distance above the surface, so that they became entirely submerged, and they rose to the surface naturally. The surface tension of the water was found to be sufficient to float weevils which were placed upon it carefully. The generally hairy condition of the surface of the weevil's body prevents it from being readily wetted, so that it may struggle for some time in the water without becoming really wet. When dropped, as described above, weevils float head downward, with the tip of the abdomen above the surface. In the submergence tests weevils were held down by a wire screen, and all bubbles were removed from their bodies by a pipette, thus making the tests as severe as possible.

Sixty squares believed from external examination to be infested were floated in a driving rain for six hours. They were then removed and left for several days, during which time 75 per cent of them produced normal adults. Ten squares which were floated in driving rain for six hours were opened at once, and in every case found to be only slightly moist on the inside. These contained six larvæ and four pupæ, and all were in perfect condition.

As squares float normally, submergence tests were considered extreme. Five squares were submerged for six hours, and after that produced three normal adults; one pupa died, and one square was found

to have been uninfested. Five more squares were submerged for 31 hours. These produced two normal adults, and one pupa died in the process of molting after removal from the square. Death was probably caused in the last case by drying; one square was found to contain a dead pupa, and one was not infested. To test the possibility of its living, should the square be penetrated by water, a naked pupa was submerged for six hours, but in spite of this unusual treatment it produced a normal adult. Numerous larvæ removed from squares and placed in water pupated in one or two days, and several pupæ remained alive, though floating for several days in water before they transformed into adults.

In the case of squares floating normally it is evident that they might remain in water for several days without injury to the weevil within. Very slight wetting of the cell takes place, even under the extreme conditions of submergence. The effect of a brief flood would not, therefore, be at all injurious. As adults float as readily as do squares, they may also be carried long distances, and, furthermore, they are able to crawl out of the water upon any bushes, weeds, or rubbish which they touch. Even when floating for several days continuously they are able to live and may be carried directly to new fields. The floating of adults and infested squares explains the appearance of weevils in great numbers along high-water lines immediately after a flood.

Field observations were made to supplement the laboratory experiments recorded in the preceding paragraphs. In July, 1904, many fields in the vicinity of Victoria, Tex., were partially and some wholly submerged. This condition lasted for several days. Examination made after the recession of the water showed that many fallen squares which had been in the water for some time contained uninjured larvæ and pupæ. Naturally, eggs and larvæ found in squares upon the plants, even though under water for some time, escaped unharmed. Weevils were working normally upon the plants. No diminution in their numbers could be seen, and it was apparent that the overflow caused no check either to the development of the immature stages or to the activity of the adults.

## PLANT CONTROL.

While climate is the foremost factor in the control of the boll weevil and also of the behavior of the cotton plant, there are certain kinds of control which the plant itself exerts. One of the most important of these is proliferation, which will be discussed in the following paragraphs.

### PROLIFERATION.

Early in the investigation of the boll weevil it was noticed that the immature stages and sometimes even the adults are frequently killed by a form of reaction of the plant known as proliferation.[1] It appears that this property of the plant might be emphasized by breeders. For this reason special studies were conducted in 1905

[1] Dr. O. F. Cook, of the Bureau of Plant Industry, has published a number of papers in which references are made to proliferation. The reader is referred to these papers, which are included in the bibliography at the end of this bulletin, for a full discussion of the botanical aspects of the phenomenon.

and 1906. The results were published in Bulletin 59 of the Bureau of Entomology from which the following statements are abstracted.

For the present purposes proliferation may be defined as the development of numerous cells from the parts of the bud or boll of the cotton plant which are injured by the weevil. It is clearly a manifestation of an inherent tendency on the part of the plant to counteract irritation by the growth of large numbers of new cells. This growth usually begins in the layer of cells adjoining the lining of the boll or in the staminal column of the undeveloped bloom. Part of the formation may project through the rupture made by the weevil or may form a hemispherical mass protruding from the inner side of the carpel of the boll and pressing into the lock. The reaction on the part of the plant begins generally before the egg hatches. In some cases the egg itself may be moved a considerable distance by the growth. In other instances the egg becomes enveloped and the larva emerges in the proliferous mass. Under such circumstances it may be destroyed early in life, although it often makes its way through the mass into portions of the fruit which have not been affected. As the larva feeds it continues and increases the irritation, and the response of the plant is immediate. In this way it often happens that the space the larva has eaten out becomes filled by the proliferous mass, and the pressure becomes so strong that eventually the larva or the resulting pupa or adult is crushed. It is clear from the observations made that it is this crushing effect that destroys the weevil. (See Pl. XIV, *b*.) A number of experiments in which weevil larvæ were placed in proliferous tissues showed that they could develop normally upon this modification of their natural food.

The frequency of the occurrence of proliferation was determined by the examination of 1,870 squares and 2,042 bolls of a large number of American and several foreign cottons. In the case of squares, it was found that in the averages for all seasons and localities proliferous growth followed feeding punctures in 48 per cent of the cases. The highest percentage, 75, was in the case of the Jannovitch, an Egyptian variety. In the case of bolls, proliferation followed in 81 per cent of the cases of feeding punctures. It is consequently apparent that proliferation occurs more frequently as a result of feeding punctures in bolls than in the case of punctures in squares.

No very satisfactory results followed a study of the effect of climatic conditions upon the frequency with which proliferation follows the attack of the weevil. The observations included a number of varieties growing in two localities during two seasons, but there seems to be no special relation between the locality and the season and the number of cases in which proliferation was found. In fact, the maximum percentage of formation of proliferation in bolls and the minimum in squares occurred at the same time in the same locality and with the same variety.

Table LXII shows the weevil mortality due to proliferation in squares and bolls under natural conditions.

TABLE LXII.—*Summary of observations showing increased mortality of the boll weevil in squares and bolls caused by proliferation.*[1]

| Years of observations. | Localities covered. | Varieties included. | Squares examined. | | | Mortality in squares. | | Increase in mortality due to proliferation. | Bolls examined. | Locks examined. | | | Mortality in locks. | | Increase in mortality due to proliferation. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total number. | Number with proliferation. | Per cent with proliferation. | With proliferation. | Without proliferation. | | | Total number. | Number with proliferation. | Per cent with proliferation. | With proliferation. | Without proliferation. | |
| | | | | | | P. ct. | P. ct. | P. ct. | | | | | P. ct. | P. ct. | P. ct. |
| 1902 | 4 | 4 | 105 | 44 | 41.9 | 30.5 | 19.5 | 11.0 | | | | | | | |
| 1903 | 1 | 1 | | | | | | | 246 | 1,033 | 434 | 42.0 | 15.0 | 5.0 | 10.0 |
| 1903 | 1 | 1 | | | | | | | 452 | 1,898 | 995 | 52.4 | 28.4 | 12.8 | 15.6 |
| 1904 | 1 | 9 | 2,954 | 1,480 | 50.0 | 9.6 | .6 | 9.0 | | | | | | | |
| 1904 | 2 | 2 | | | | | | | 398 | 1,708 | 885 | 51.8 | 18.2 | 11.1 | 7.1 |
| 1905 | 1 | 14 | 4,504 | 2,365 | 52.5 | 19.6 | 5.5 | 14.1 | | | | | | | |
| 1905 | 1 | 6 | 771 | 372 | 48.2 | 28.6 | .3 | 28.3 | | | | | | | |
| 1905 | 1 | 1 | 443 | 212 | 47.9 | 25.1 | 9.7 | 15.4 | | | | | | | |
| 1905 | 1 | 4 | 144 | 40 | 27.8 | 34.8 | 3.2 | 31.6 | | | | | | | |
| 1905 | 1 | 14 | | | | | | | 1,802 | 7,821 | 5,069 | 64.8 | 16.7 | 8.5 | 8.2 |
| 1905 | 1 | 1 | | | | | | | 82 | 254 | 158 | 62.2 | 14.6 | .0 | 14.6 |
| Totals and averages | | | 8,921 | 4,513 | [2]50.6 | [2]17.2 | [2]3.7 | [2]13.5 | 2,980 | 12,714 | 7,541 | [2]59.3 | [2]15.5 | [2]9.2 | [2]6.3 |

[1] From Bulletin 59, Bureau of Entomology, p. 27. [2] Weighted average.

It will be seen that in the case of squares there was a range of from 9 to 31 per cent increase in the mortality due to proliferation, the general average being 13 per cent. In bolls the range is not so great, being only from 7 to 15 per cent, while the average increase in mortality in bolls was found to be 6 per cent. This is slightly less than one-half as great a mortality as was found to be the case in squares.

A number of interesting experiments were performed to determine whether artificial punctures were as frequently followed by proliferation as those made by the weevil. One thousand one hundred and three needle punctures were made, resulting in proliferation in 36 per cent of the cases. This percentage is not so large as in the case of feeding punctures of the weevil, but it is as large as could be expected when the difference between a clean needle puncture and the rough, lacerating puncture by the weevil is considered. It consequently appears that it is the mechanical injury of the weevil rather than any secretion which causes the growth. A further series of experiments showed that injections of caustic potash, formic acid, and other chemicals did not appear to increase the number of cases in which proliferation followed. It did appear, however, that unsealed artificial punctures resulted in more frequent proliferations than sealed punctures of the same kind.

A number of experiments were instituted to show the possible effect of heavy fertilization of the cotton plant upon its tendency to form proliferous tissues. It was supposed that some such cultural expedient as fertilization might increase the resistance on the part of the plant. In the case of over 8,000 observations made on fertilized cotton growing in two localities, however, it was found that proliferation followed attack by the weevil practically as frequently in the one case as in the other. Squares on fertilized plats showed proliferation in 50.5 per cent of the cases; on unfertilized plats in 49.5 per

cent. Bolls on fertilized plats showed proliferation in 66.2 per cent of the infested locks; on unfertilized plats in 69.5 per cent.

It was found that proliferation very frequently follows the attacks of any of the insects which injure the cotton boll or square. In the case of these other insects the phenomenon is of little importance, since, unlike the weevil, they generally make punctures merely for the purpose of feeding. The immature stages are not developed in the cotton fruit and are consequently beyond the reach of the growth which the adults have incited.

### OTHER PHASES OF PLANT CONTROL.

There are other forms of plant control which require attention. Dr. O. F. Cook, of the Bureau of Plant Industry, has been the principal student of this matter and has called attention to numerous weevil-resisting adaptations of the cotton plant, although important contributions have been made by several other investigators. Among the more important properties or tendencies of the cotton plant which affect the weevil adversely are: (1) Early bearing, (2) determinate growth, (3) hairy stalks and stems (Pl. XIV, *a*), (4) abundance of secretion from nectaries, (5) pendent bolls, (6) involucral bracts grown together at base, (7) thick-walled bolls, and (8) tendency to retain infested fruit (Pl. XV).

Early bearing enables the plant to produce its fruit before the weevils have become numerous. In other words, it allows the plant to take advantage of the small number of weevils which succeed in passing the winter and also to take advantage of the comparatively slow development of the insect during the early portion of the growing season.

Determinate growth prevents the maturity of numerous weevils in the fall. Plants with this character well marked discontinue both growth and fruiting. As the capacity of the weevil to increase is limited very largely by the amount of fruit available, it is evident that a variety which discontinues fruiting at an early date in the fall must reduce greatly the number of weevils that are present to go into winter quarters.

It has been found that the presence of a considerable growth of hair on the stalks and stems presents an important obstacle to the progress of the weevil and consequently reduces the daily capacity of damage of each insect. In some of the American upland varieties, notably the King, this hairiness is developed to such an extent as to be a form of protection of considerable importance.

As has been pointed out in another section of this bulletin, boll-weevil parasites in the adult stage feed upon the nectar which is secreted by the cotton plant. Consequently the greater the secretion of nectar the more favorable will be the conditions for these important enemies of the weevil.

There is a more or less constant tendency on the part of the adult weevil to frequent the upper portion of the cotton plant. If it happens to alight upon a lateral branch which has bolls or squares standing upright, attack follows immediately. On the other hand, if the branch upon which the weevil alights has bolls which turn downward, there is a considerable likelihood that it will work upward to other lateral branches and overlook the fruit upon the first branch.

The weevil has frequently been observed to experience considerable difficulty in reaching the cotton square through the involucral bracts. If these bracts are united at the base, or very closely appressed, or have their edges provided with strong hairs, the natural difficulty the weevil experiences will be increased.

Dr. Cook has pointed out that certain Central American strains of cotton have bolls provided with thick interior walls, which in some cases the weevil is unable to penetrate.

As has been pointed out in another section, the insect enemies of the boll weevil find the infested squares which remain on the plants more suitable for attack, and are able to raise the average control above that in fallen squares in most sections. Consequently it is of advantage to the planter to have a variety with a well-marked tendency to retain the infested fruit. The ability to retain the infested squares is explained under the heading of parasite attack (p. 144).

Several other peculiarities of the cotton plant which Dr. Cook has interpreted as weevil-resisting adaptations are described in Bulletin 88 of the Bureau of Plant Industry of this department.

## DISEASES.

Little attention has been given to the study of diseases of the boll weevil because the observations upon the mortality of the insect have not indicated any great amount of death due to causes which could not be well explained under the headings of climatic, plant, parasitic, and predatory control. There is no doubt that bacterial and fungous diseases sometimes attack the weevils, especially those hibernating in moist places. Only two definite records are at hand of death by fungus, and these have been recorded in former bulletins. One was a case of a new species of Aspergillus and the other of a species of Cordyceps.

## PARASITIC AND PREDATORY INSECT ENEMIES.

Recent work has added very greatly to our knowledge of the insect enemies of the boll weevil. Much remains to be done, however, since it has been found that the boll weevil is accumulating species after species of parasites as it advances farther into the United States. A recent publication of this bureau (Bulletin No. 100) has dealt rather extensively with the insect enemies of the boll weevil. In the present publication, therefore, only a few of the more important facts learned will be considered.

### A BRIEF SUMMARY OF THE INSECT SPECIES ATTACKING THE BOLL WEEVIL.

At the present time the boll weevil is known to be the host of 29 species of parasites, of which 4 are mites, 21 belong to the order Hymenoptera, and 5 are parasitic flies. In addition to these true parasites, there are 6 predators which kill the adult boll weevils and 22 predators which attack the immature stages. These include a mantis, a predatory bug, 8 beetles, a leaf-feeding caterpillar, and 17 species of ants. In all, the boll weevil is known to have 58 species

*Fig. a.*—Cotton squares with short abscisss layer, permitting infested squares to fall. (Original.)

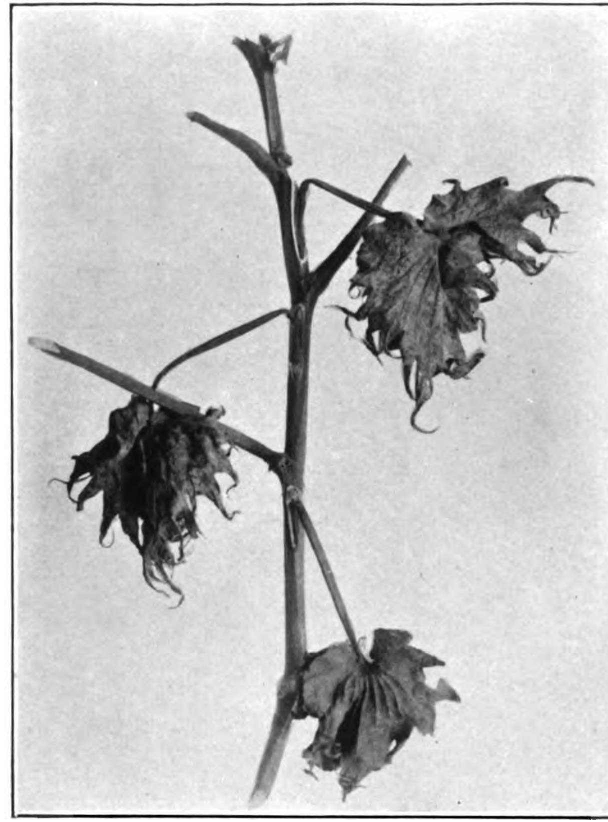


*Fig. b.*—Cotton squares with long abscisss layer, retaining infested forms to hang and dry. (Original.)

THE DIFFERENCE BETWEEN HANGING AND FALLEN SQUARES.

of insect enemies, and probably many more species will be found as the weevil enters new regions. In fact, records of parasite and ant attack have been found as early as two weeks after invasion of new territory.

ARACHNIDA. ACARINA. SARCOPTOIDEA.

*Pediculoides ventricosus* Newport.—This mite has been prominent in the study of the boll weevil since its first notice (Rangel, 1901) under the name of *Pediculoides ventriculosus*. These mites reproduce viviparously, and their offspring are mature and fertile at birth. After attachment to a host the abdomen begins to inflate until it becomes many times greater than the thorax. The time required for engorgement varies from two to five days. An average of 100 female offspring to an individual has been recorded.

*Pediculoides* n. sp.—This mite was discovered in the laboratory at Dallas, Tex., June 13, 1907, by the junior writer. Observations continued for some time proved that there was a generation about every four days. The mite has been found attacking several other species of weevils as well as many other insects.

*Tyroglyphus breviceps* Banks.—This species has been recorded as an enemy of the boll weevil from Victoria, Tex. A similar mite has also been found at Calvert, Tex.

GAMASOIDEA.

*Macrocheles* n. sp.—Mr. Harry Pinkus found this mite very common in the fallen cotton squares at Tullulah, La., during August, 1911, feeding upon the boll-weevil stages. It has not been definitely proved that the species kills the weevil, but the evidence is more or less conclusive.

INSECTA. ORTHOPTERA. MANTIDÆ.

*Stagmomantis limbata* Hahn.—This insect has been found to prey upon the adult boll weevil in Texas.

HETEROPTERA. REDUVIIDÆ.

*Apiomerus spissipes* Say.—This predatory bug has been recorded by Mr. A. C. Morgan as an enemy of the adult boll weevil in Texas.

COLEOPTERA. CARABIDÆ.

*Evarthrus sodalis* Le Conte.—This species (fig. 31) is a predator upon the adult boll weevil in Louisiana and Texas.

*Evarthrus* sp.—Another species of the genus has been recorded by Newell and Trehearne as predatory upon adult boll weevils at Baton Rouge, La.

CANTHARIDÆ.

*Chauliognathus* spp. (see fig. 32).—The larvæ of these beetles are very common in the squares and bolls of cotton in Louisiana and Mississippi. In one instance undoubted proof of the attack of such a larva upon a boll-weevil larva was recorded.

CLERIDÆ.

*Hydnocera pallipennis* Say.—A single beetle of this species was reared April 6, 1907, from the boll weevil, collected August 28, 1906, at Waco, Tex.

FIG. 31.—*Evarthrus sodalis*, an enemy of the boll weevil. (Original.)

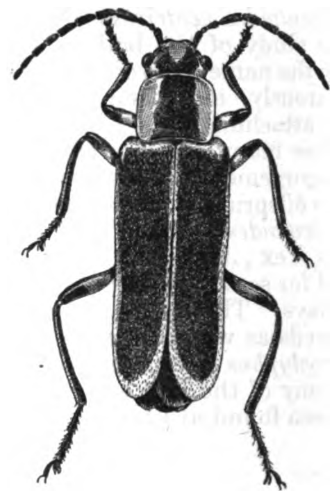


FIG. 32.—*Chauliognathus marginatus*, an enemy of the boll weevil. (Original.)

*Hydnocera pubescens* Le Conte (fig. 33):—This is a very common breeder in the weevil cells. Its larvæ have been not only found feeding upon the various weevil stages, but have been frequently observed feeding upon the parasites of the weevil.

CUCUJIDÆ.

*Cathartus gemellatus* Duval.—This beetle is a predator and scavenger, its larvæ being frequently found feeding upon boll-weevil stages which they must have killed.

TENEBRIONIDÆ.

*Opatrinus notus* Say.—This beetle has been found by Mr. Harry Pinkus at Tallulah, La., to prey as an adult upon the immature stages of the weevil in fallen squares during July. It occurred very commonly in the cotton fields.

LEPIDOPTERA. NOCTUIDÆ.

*Alabama argillacea* Hübner.—For many years the ravages of the cotton leaf worm attracted almost as much attention in some portions of the South as does the damage by the boll weevil now. Various changes in the system of cultivation of cotton in the South have combined to reduce the damage done by this pest, and, moreover, a very effective method of controlling it, by the use of Paris green, was discovered. It is one of the striking occurrences in the history of economic entomology that this formerly dreaded pest is now looked upon by the farmers in weevil-infested regions as decidedly beneficial.

When the plants become defoliated by the leaf worms the growth is checked, and consequently the opportunities for the breeding of the weevils in additional squares are reduced. This results in a marked decrease in the number of weevils at the end of the season. This decrease has not so much effect upon the crop of the current year as upon the following one by reason of the lessened number of weevils that pass through hibernation. Moreover, when the plants have been deprived of most of their leaves the worms very frequently devour the squares and sometimes small bolls in which the immature stages of the boll weevil are located. In this way the leaf worm acts directly as a remedial agency against the boll weevil. This work to some extent accomplishes the same result as the fall destruction of the plants, which, as is well known, is the greatest single factor in the successful production of cotton in weevil-infested regions. There is still another consideration in this connection, namely, that the defoliation of the plants allows the sun to strike the squares upon the ground, thus destroying many of the larvæ and pupæ of the weevil contained therein. At the present time, as the result of the conditions mentioned, the planters in the infested regions are rapidly giving up the practice of poisoning the formerly much dreaded caterpillar. If, as may occasionally happen, the plants become defoliated before the weevils reach the maximum numbers in the fields, the damage of the one insect will simply be added to the damage of the other. In that event the use of poison will be necessary.[1]

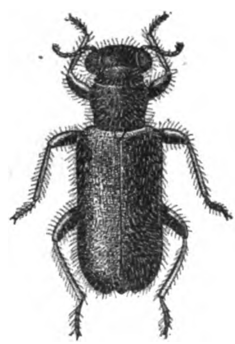


FIG. 33.—*Hydnocera pubescens*, an enemy of the boll weevil. (Original.)

In the extensive defoliation by the leaf worm in 1911 one of the most striking features was the scattering of the boll weevil for great distances into new territory. The general absence of green fields caused the weevils to fly much farther than they would otherwise have done.

### HYMENOPTERA. FORMICOIDEA. DORYLIDÆ.

*Eciton (Acamatus) commutatus* Emery (Pl. XVI, *a*).—This ant has been observed only once, at Beeville, Tex., attacking the weevil larvæ in squares.

### PONERIDÆ.

*Ectatomma tuberculatum* Olivier.—The "kelep," or so-called Guatemalan ant, is a native of Mexico and Central America. Like all other ponerids, it is slow in action, but is able to capture such weevils as come within its reach on the cotton plants. Numerous attempts to establish this species in the United States have failed.

### MYRMICIDÆ.

*Cremastogaster lineolata* Say, subsp. *læviuscula* Mayr, var. *clara* Mayr. (Pl. XVI, *b*).—This ant, although normally a honeydew feeding species, is also an enemy of the immature stages of the boll weevil in Texas.

*Solenopsis geminata* Fabricius, var. *diabola* Wheeler.—The common fire ant of the Southern States is one of the best enemies of the boll

[1] The above paragraph is from W. D. Hunter in the Yearbook of the Department of Agriculture for 1904, p. 201.

weevil, being very industrious in its search for infested squares, which it enters in great numbers.

*Solenopsis molesta* Say (Pl. XVI, *e*).—This minute ant was taken in the act of attacking a boll-weevil larva at McAlester, Okla., by Mr. R. A. Cushman.

*Solenopsis texana* Emery.—This ant is a common enemy of the immature stages of the boll weevil in Texas, Louisiana, and Mississippi.

*Monomorium minimum* Buckley.—The common house ant is a very valuable enemy of the boll weevil in Texas, Louisiana, and Mississippi.

*Monomorium pharaonis* Linnæus (Pl. XVI, *d*).—This cosmopolitan house ant is another of the more important boll-weevil enemies in Texas, Louisiana, and Arkansas.

*Pheidole sp.* near *flavens*.—This species was found abundantly attacking the immature stages of the boll weevil at Arlington, Tex., August 31, 1908, by Mr. R. A. Cushman.

*Pheidole crassicornis* Emery.—This species was found as an abundant enemy of the immature stages of the weevil at Lampasas, Tex., September 23, 1908, by Mr. R. A. Cushman.

### DOLICHODERIDÆ.

*Forelius maccooki* Forel.—This ant has been recorded at several places in Texas as an enemy of the immature stages of the boll weevil.

*Dorymyrmex pyramicus* Roger (Pl. XVI, *c*).—The so-called lion ant of Cuba was recorded by Mr. E. A. Schwarz (1905) as protecting solitary tree cotton from the boll weevil.

*Dorymyrmex pyramicus* Roger, var. *flavus* Pergande.—This common cotton-field ant has only once been recorded definitely as an enemy of the boll weevil. This record is from Texarkana, Tex., by Mr. R. C. Howell.

*Iridomyrmex analis* Ern. André. (Pl. XVI, *f*).—This common ant is normally a honey-loving species, but occasionally attacks insect food. It has been found attacking the boll weevil by Dr. W. E. Hinds.

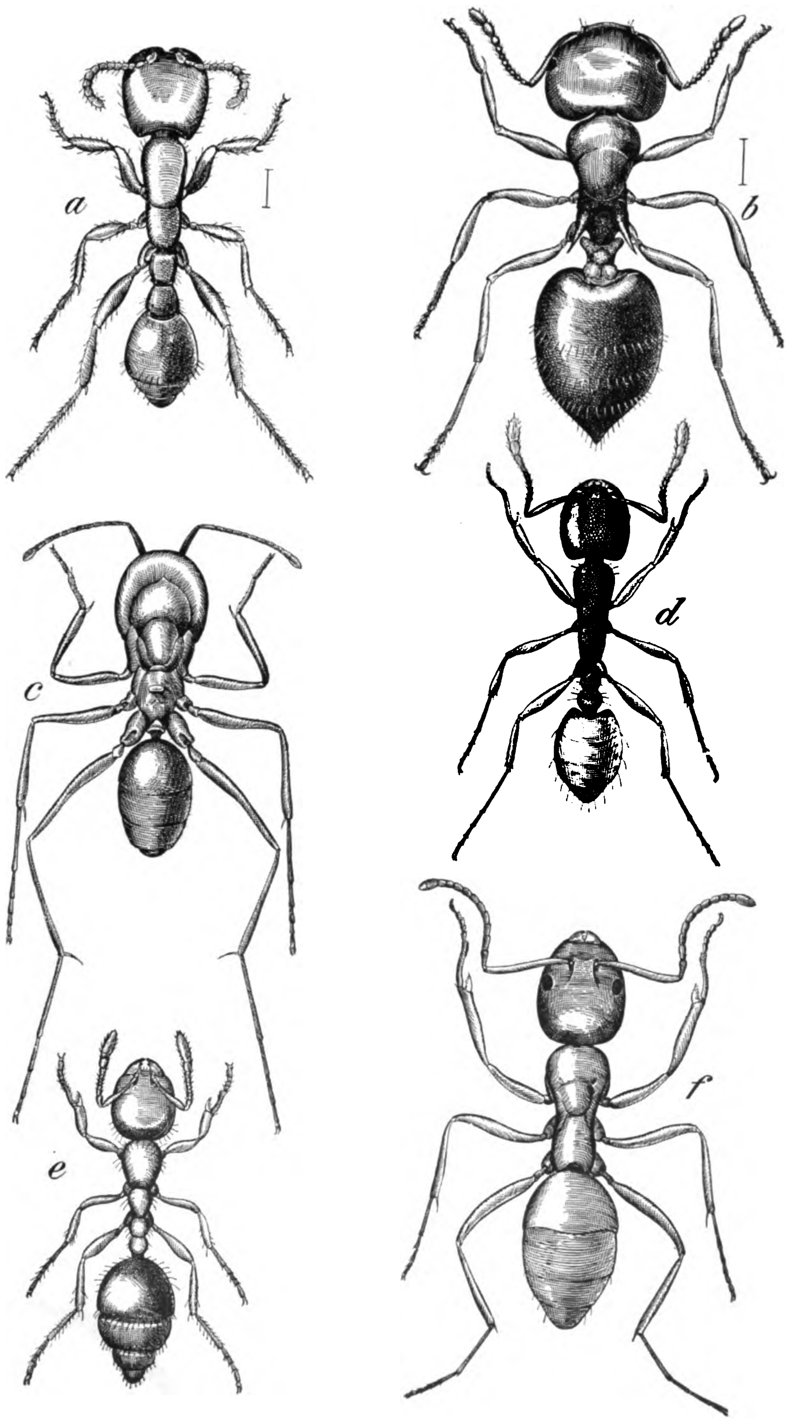
*Iridomyrmex humilis* Mayr.—The Argentine ant has formerly been recorded as an enemy of *Solenopsis geminata*, *Monomorium pharaonis*, and *Iridomyrmex analis*, three of our common boll-weevil enemies. Mr. T. C. Barber has recently reported that the Argentine ant, by continually worrying the boll weevils and killing newly emerged adults, practically cleared a heavily infested cotton patch at Baton Rouge, La., in September, 1909, at a time when fields outside of the ant territory were still very seriously infested.

### FORMICIDÆ.

*Formica subpolita* Mayr, var. *perpilosa* Wheeler.—This species is normally a honey feeder, but has been recorded by Rangel (1901) as a predator upon adult weevils in Mexico.

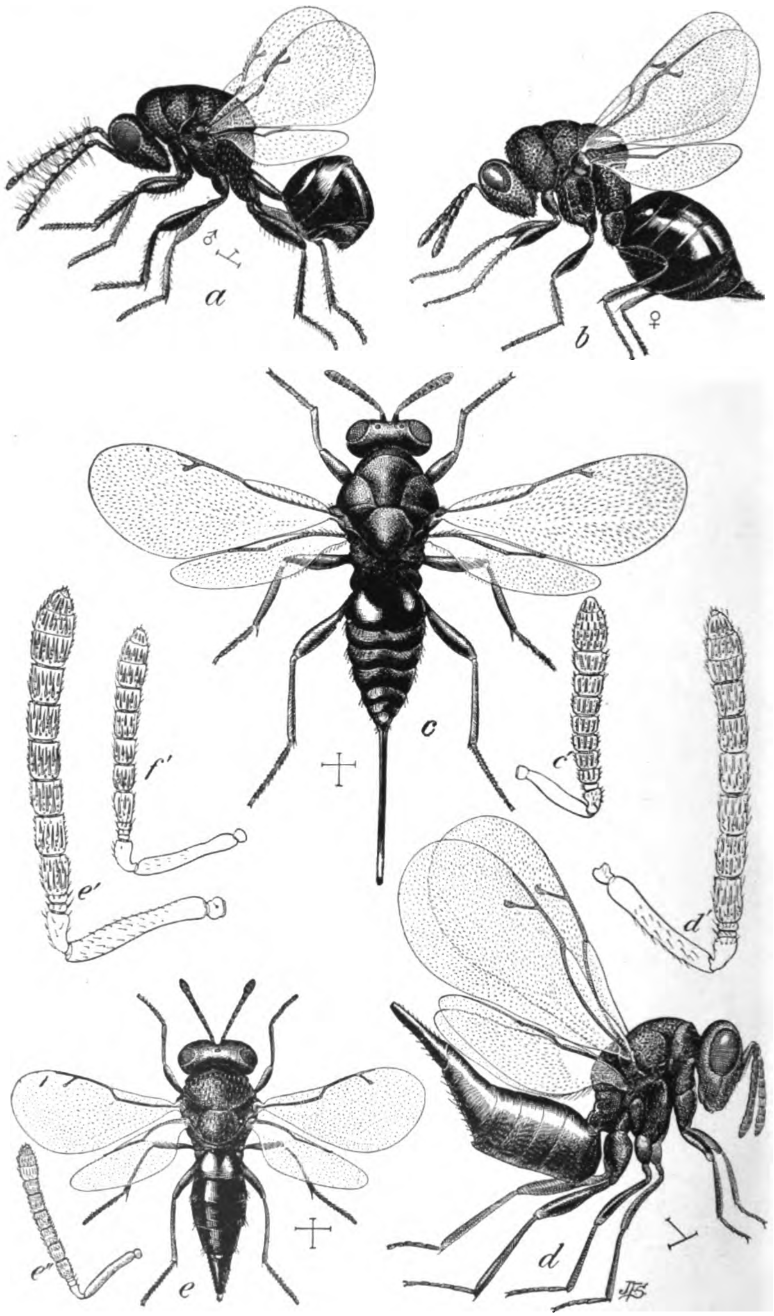
*Formica pallidi-fulva* Latreille.—A single instance of this species cutting its way into a boll weevil-infested square was observed by Mr. C. E. Hood at Ashdown, Ark., September 2, 1908. The species is commonly found on the cotton plants.

*Prenolepis imparis* Say.—Mr. C. E. Hood recorded this species as an enemy of the immature stages of the boll weevil at Ashdown, Ark., September 2, 1908.




BOLL-WEEVIL ANTS.

*a, Eciton commutatus; b, Cremastogaster lineolata; c, Dorymyrmex pyramicus; d, Monomorium pharaonis; e, Solenopsis molesta; f, Iridomyrmex analis.* (Original.)




**BOLL-WEEVIL PARASITES.**

*a*, *Eurytoma tylodermatis*, male; *b*, *Eurytoma tylodermatis*, female; *c*, *Microdontomerus anthonomi*, female; *c'*, antenna of same; *d*, *Habrocytus piercei*, female; *d'*, antenna of same; *e*, *Catolaccus hunteri*, female; *e'*, antenna of same; *f'*, antenna of *Catolaccus incertus*. (Original.)

### HYMENOPTERA. CHALCIDOIDEA. CHALCIDIDÆ.

*Spilochalcis* sp.—A single male of this species was found dead in a weevil cell with the remains of the weevil and its own exuvium August 10, 1907, at Victoria, Tex.

### TORYMIDÆ.

*Microdontomerus anthonomi* Crawford (Pl. XVII, *c*).—This is one of the most important parasites of the boll weevil in Texas and Louisiana. It is generally found throughout the year and is known to attack two other species of weevils.

### EURYTOMIDÆ.

*Eurytoma tylodermatis* Ashmead (Pl. XVII, *a*, *b*).—This species ranks among the five most important boll-weevil parasites, and its range is practically coextensive with that of its host. It is known to attack 14 other species of weevils.

*Eurytoma* sp.—Two species of this genus were reared from hanging squares collected August 10, 1907, at Victoria, Tex.

*Bruchophagus herreræ* Ashmead.—This parasite has been recorded from the boll weevil from Mexico, but the name is thought to be a synonym of *Eurytoma tylodermatis*.

### PERILAMPIDÆ.

*Perilampus* sp.—A single individual was reared from the boll weevil by isolation from material collected September 7, 1907, at Shreveport, La., by Mr. C. E. Hood. Considerable doubt has been raised concerning this record by authorities upon the breeding habits of Perilampidæ.

### ENCYRTIDÆ.

*Cerambycobius cyaniceps* Ashmead (Pl. XVIII, *f*).—The range of this species is coextensive with the boll weevil in the United States. It is extremely important in northern Louisiana and Arkansas, and is known to attack 17 species of weevils.

*Cerambycobius cushmani* Crawford.—This species is evidently limited to southern Texas, where it is occasionally important. It is known as a parasite of four other species of weevils.

*Cerambycobius* sp.—On February 23, 1909, a male of a green species of this genus was reared from a weevil in squares collected at Natchez, Miss., on January 19.

### PTEROMALIDÆ.

*Catolaccus hunteri* Crawford (Pl. XVII, *e*).—This is one of the most important parasites of the boll weevil. It is of greatest importance in Louisiana and Mississippi. Twelve other species of weevils are known as hosts.

*Catolaccus incertus* Ashmead (Pl. XVII, *f'*).—This is also a very important species and occurs throughout the infested region. It is also a parasite of 13 other species of weevils.

*Habrocytus piercei* Crawford (Pl. XVII, *d*).—This brilliant green parasite has been reared from the boll weevil only in the fall and winter months in Louisiana and Texas. One other weevil host is known.

*Lariophagus texanus* Crawford (Pl. XVIII, *a*).—There is strong evidence that this species is a primary parasite of the boll weevil in southern Texas. It is also undoubtedly a parasite of four other species of weevils.

EULOPHIDÆ.

*Tetrastichus hunteri* Crawford (Pl. XVIII, *b*, *c*).—This parasite of the boll weevil has been known only since 1908. It is the only internal hymenopterous parasite of the weevil and occurs commonly in Louisiana and Mississippi and has been recorded from Texas. It is evidently more important in the fall of the year.

ICHNEUMONIDEA. ICHNEUMONIDÆ.

*Pimpla* sp.—On February 23, 1909, a single female of this species was reared from a weevil larva collected at Nacogdoches, Tex., on January 27.

BRACONIDÆ.

*Sigalphus curculionis* Fitch.—This common parasite of the plum curculio has been found frequently attacking the boll weevil in Louisiana and Mississippi. It is known as a parasite of eight other species of weevils.

*Urosigalphus anthonomi* Crawford.—This species has been reared from the boll weevil only at Brownsville, Tex.

*Urosigalphus schwarzi* Crawford.—This species is a parasite of the boll weevil in Guatemala and has never been reared in the United States.

*Urosigalphus* sp.—A single specimen of this species was reared in 1909 at Arlington, Tex.

*Microbracon mellitor* Say.—Until 1909 this was the most important parasite of the boll weevil. It is coextensive in distribution with its host, but is by far most important in Texas and Oklahoma. It is known as a parasite of 10 other species of weevils.

An unknown braconid, nearly related to Glyptocolastes, was reared from the boll weevil in southern Texas.

DIPTERA. PHORIDÆ.

*Aphiochæta nigriceps* Loew.
*Aphiochæta fasciata* Fallen.
*Aphiochæta pygmæa* Zetterstedt.

These three species and also possibly others in this genus have frequently been found feeding upon boll-weevil larvæ and in many cases under such circumstances that they must be assumed to be parasites as well as scavengers.

TACHINIDÆ.

*Myiophasia ænea* Wiedemann.—This fly has been recorded as a parasite of the boll weevil in Texas. It is also an enemy of six other species of weevils.

*Ennyomma globosa* Townsend (Pl. XVIII, *d*, *e*).—This fly is an important parasite of the boll weevil in Louisiana. It also attacks the cowpea curculio.

Careful studies have proved that the 29 species of parasites are all derived from native hosts, which are mainly weevils breeding in weeds and other plants growing normally around the cotton fields. Some of these parasites have lived for many generations on certain common weevils until suddenly some abnormal condition has decimated the numbers of the normal hosts or freed the parasites of their normal control, thus upsetting the natural equilibrium between them and their hosts. In this way the parasites have been compelled to seek new hosts, and the presence of the boll weevil in large numbers has led them to attack it. This has been demonstrated by the sudden adaptation of several species of parasites at Victoria, Tex. These were normally enemies of the huisache pod weevil, but were unable to attack this insect in 1907 because of the failure of the huisache trees to fruit. Another demonstration of sudden adaptation was found in the sudden increase of attack by *Eurytoma tylodermatis* following the cutting of a number of weeds in which this parasite was attacking a native weevil. Such adaptability of course suggests the advisability of keeping the weeds in the vicinity of cotton fields cut down during the summer in order to force the parasites to attack the boll weevil.

After a parasite has once attacked a new host it becomes comparatively easy for succeeding generations to repeat the attack. In this manner many species of weevil parasites have increased their range of hosts until they have obtained a complete series extending throughout the year. A rotation of hosts has, therefore, been established. As many as 17 different weevils are attacked by one of the species of boll-weevil parasites. To illustrate the value of this rotation we have but to quote one of the commonest examples. The strawberry and blackberry bud weevil is very common in the South in the latter half of March and until June. Two of the species of the boll-weevil parasites attack this weevil as soon as it begins to breed, and they are able to develop at least one generation before the boll weevil can begin its attack on the cotton squares. These parasites are found attacking the boll weevil throughout the summer. In the fall they begin to attack certain stem weevils, such as the potato or Solanum stem weevils, and produce a generation during the winter which emerges in time to attack the strawberry weevil. Thus, two generations are developed while the boll weevil is in hibernation. To obtain a practical benefit from this rotation of hosts it is only necessary to have a hedge of dewberries or blackberries along the fences.

It is of extreme importance to know that no matter what exigencies reduce the boll weevils, the parasites, though also reduced in numbers, will still be conserved on their native hosts and will attack the boll weevils again as soon as they become sufficiently numerous.

The location of the developing stages of the weevil is of much importance to the insect enemies. (See Pl. XV.) It has been found that cotton varieties display two distinct tendencies in their response to injury to their fruit. Certain varieties, such as King, Simpkins, and Shine, are distinguished by a transverse ring at the base of the pedicel of the square and boll. When the square or boll is badly injured, the plant immediately cuts off circulation by forming a corky layer at this ring, and the injured member falls to the ground. Other varieties, such as Dickson, Rublee, and in general the cluster

and semicluster types, are distinguished by an elliptical mark which encircles the pedicel, but extends down the stem for one-half to a whole inch or more, and is usually incomplete at the lower end. When such a square is injured, the corky layer is of course diagonal, extending downward on the stem, but usually incomplete, so that the injured member adheres by a thread of bark and dries on the plant. A very extended series of observations has definitely proved that the hanging dry infested square is the most favorable place for parasitic control and that the total control of the weevil by all causes increases in proportion to the number of these hanging dry infested squares. A proper selection of varieties is, therefore, a practical method of increasing control.

On the other hand, it must be understood that insect control of the stages in fallen squares is often very high. Certain parasites and all of the ants and predatory beetles are more likely to find the immature weevils in the soft moistened or dried fallen squares than in the dry hanging squares. Thus the developing weevil has enemies wherever it is. The parasite control on the ground will be obtained best by the methods of cultivation to be mentioned hereafter.

The adjustment of new species of parasites and predators in each new region makes it apparent that the boll weevil will everywhere be attacked by those species of insects most fitted to attack it under the existing local conditions. This attack will be of greatest importance in regions where humidity tends to reduce the effectiveness of other forms of control.

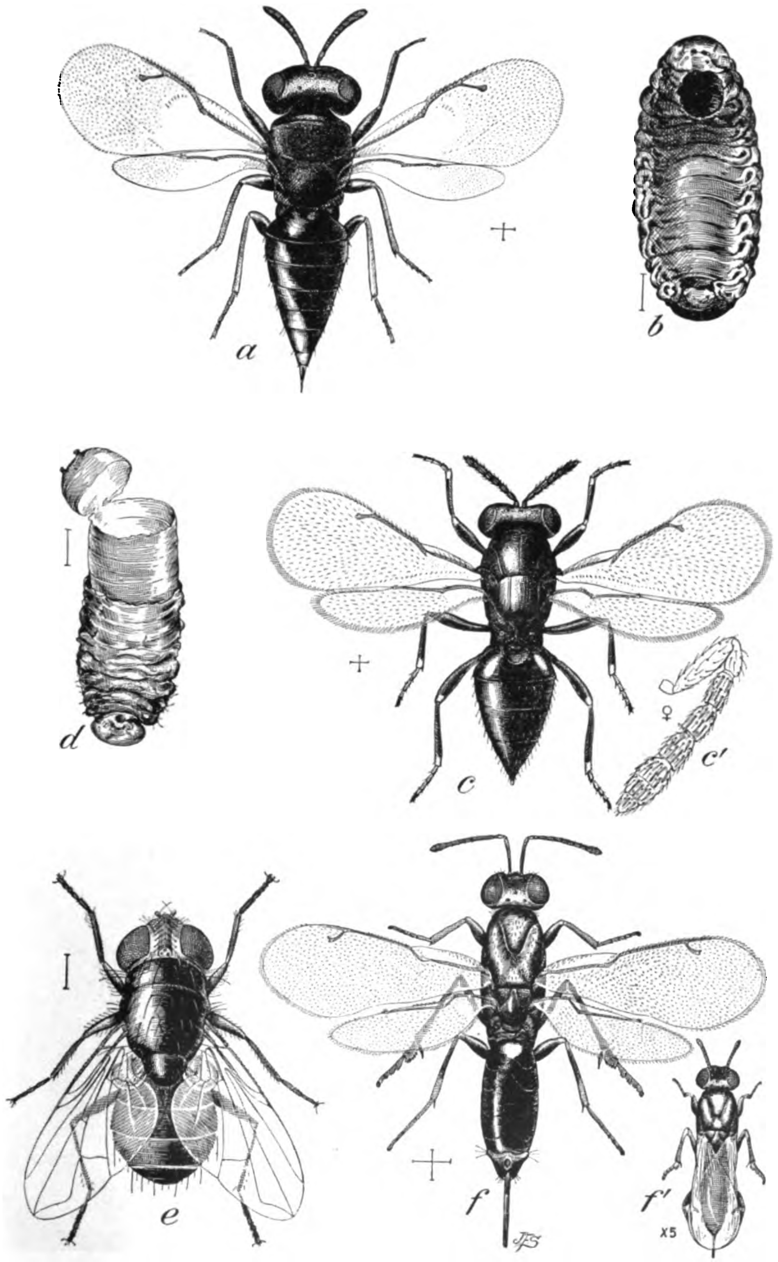
By Table LXIII we show the final summary of the records of parasitism made for a period of years to illustrate the fact that this is a factor of great importance.

TABLE LXIII.—*Parasite control of the boll weevil, by years.*

| Year. | Weevil stages. | Parasites. | Mortality from parasites. |
|---|---|---|---|
| | | | *Per cent.* |
| 1902 | 602 | 7 | 1.16 |
| 1903 | 819 | 59 | 7.20 |
| 1905, March | 1,005 | 32 | 3.18 |
| 1905, August | 1,702 | 21 | 1.23 |
| 1906 | 40,073 | 1,728 | 4.31 |
| 1907 | 13,602 | 1,121 | 8.24 |
| 1908 | 29,349 | 2,952 | 10.05 |
| 1909 | 11,653 | 620 | 5.32 |
| Totals and average | 98,805 | 6,540 | 6.61 |

Table LXIII is based upon collections of squares and bolls made throughout the infested territory under a great diversity of conditions.

The average monthly parasitic and predatory control for the years 1906 to 1909, inclusive, has been arranged below (Table LXIV) to show that insects are a factor of importance throughout the year. It should be noted especially that in the months of August and September, when the boll weevils are most numerous, from 27 to 30 per cent of the immature stages are killed by insect enemies. The average for the year of 25 per cent offers great encouragement.




BOLL-WEEVIL PARASITES.

*a*, *Lariophagus texanus*, female; *b*, emergence hole of *Tetrastichus hunteri* from weevil larva; *c*, *Tetrastichus hunteri*, female; *c′*, antenna of same; *d*, puparium of *Ennyomma globosa* in weevil larva; *e*, *Ennyomma globosa*; *f*, *Cerambycobius cyaniceps*, female; *f′*, natural position of same. (Original.)

TABLE LXIV.—*Weighted average insect control of immature stages of the boll weevil, by months.*

| Month. | Forms examined. | Stages found. | Killed by parasites. | Percentage killed by parasites. | Killed by predators. | Percentage killed by predators. | Percentage killed by all insects. |
|---|---|---|---|---|---|---|---|
| January | 5,687 | 1,285 | 54 | 4.20 | 63 | 4.90 | 9.10 |
| February | 13,597 | 665 | 56 | 8.42 | 60 | 9.02 | 17.44 |
| March | 2,500 | 159 | 2 | 1.25 | 28 | 17.61 | 18.86 |
| May | 100 | 56 | 2 | 3.57 | 0 | .00 | 3.57 |
| June | 16,930 | 10,708 | 553 | 5.16 | 1,989 | 18.57 | 23.73 |
| July | 43,059 | 21,758 | 1,536 | 7.05 | 3,247 | 14.92 | 21.97 |
| August | 80,923 | 33,170 | 1,970 | 5.93 | 8,248 | 24.86 | 30.79 |
| September | 37,378 | 17,107 | 1,160 | 6.78 | 3,495 | 20.43 | 27.21 |
| October | 17,344 | 8,283 | 879 | 10.61 | 773 | 9.33 | 19.94 |
| November | 2,534 | 798 | 127 | 15.91 | 2 | .25 | 16.16 |
| December | 2,663 | 688 | 82 | 11.91 | 14 | 2.03 | 13.94 |
| Total | 222,715 | 94,677 | 6,421 | ........ | 17,919 | ........ | ........ |
| Weighted average | ........ | ........ | ........ | 6.78 | ........ | 18.92 | 25.70 |

The weighted average insect control in June, July, August, and September proves to be 26.82 per cent and for the remainder of the year 17.11 per cent.

A few records of high insect control will suffice to illustrate the extent of control under some conditions.

TABLE LXV.—*Highest records of insect control of the boll weevil.*

| Places. | Date. | Location of squares. | Stages. | Killed by insects. |
|---|---|---|---|---|
| | | | | *Per cent.* |
| Athens, Tex | Aug. 1, 1907 | Fallen | 256 | 96.11 |
| Hallettsville, Tex | Aug. 1, 1908 | ...do | 100 | 92.00 |
| Overton, Tex | Aug. 1, 1906 | ...do | 197 | 85.20 |
| Athens, Tex | Aug. 1, 1907 | Hanging | 75 | 84.00 |
| Beeville, Tex | Aug. 1, 1906 | Fallen | 1,310 | 78.80 |
| Victoria, Tex | July 29, 1908 | ...do | 375 | 78.38 |
| Beeville, Tex | Sept. 1, 1906 | ...do | 678 | 77.40 |
| Arlington, Tex | July —, 1909 | Hanging | 55 | 75.44 |
| Cuero, Tex | June 20, 1908 | Fallen | 549 | 73.60 |

The distribution of insect control in the four principal classes of forms, and also by geographical sections, has been presented in the general discussion of natural control.

## BIRDS.

Exhaustive studies of the stomachs of many birds killed in infested cotton fields by the agents of the Biological Survey of this department have emphasized the fact that the birds play a considerable part in the control of the adult boll weevils. This investigation has resulted in a list of 53 species which more or less commonly feed upon the adult weevils. In Cuba, Mr. E. A. Schwarz discovered that an oriole (*Icterus hypomelas*) has developed a habit of extracting the immature stages from the bolls and squares.

Table LXVI, which follows, is taken from Circular 64 of the Bureau of Biological Survey.

TABLE LXVI.—*Schedule of stomach examinations of birds which had eaten boll weevils.*

| Species. | During January, February, and March. | | | During April, May, and June. | | | During July, August, and September. | | | During October, November, and December. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of birds examined. | Number eating boll weevils. | Number of boll weevils eaten. | Number of birds examined. | Number eating boll weevils. | Number of boll weevils eaten. | Number of birds examined. | Number eating boll weevils. | Number of boll weevils eaten. | Number of birds examined. | Number eating boll weevils. | Number of boll weevils eaten. |
| Upland plover (*Bartramia longicauda*) | 48 | | | 13 | 1 | 1 | 1 | | | | | |
| Killdeer (*Oxyechus vociferus*) | 28 | 2 | 5 | 1 | | | 6 | | | 1 | | |
| Quail (*Colinus virginianus*) | 63 | | | 10 | | | 38 | | | 108 | 1 | 1 |
| Nighthawk (*Chordeiles virginianus*) | | | | | | | 10 | 4 | 15 | | | |
| Scissor-tailed flycatcher (*Muscivora forficata*) | | | | | | | 91 | 5 | 7 | | | |
| Kingbird (*Tyrannus tyrannus*) | | | | 10 | 1 | 1 | 22 | 6 | 8 | | | |
| Crested flycatcher (*Myiarchus crinitus*) | | | | 7 | 1 | 2 | 5 | 1 | 3 | | | |
| Phœbe (*Sayornis phœbe*) | 19 | | | | | | 2 | 1 | 1 | 13 | 3 | 3 |
| Olive-sided flycatcher (*Nuttallornis borealis*) | | | | | | | 2 | 1 | 2 | | | |
| Alder flycatcher (*Empidonax trailli alnorum*) | | | | | | | 3 | 1 | 2 | | | |
| Least flycatcher (*Empidonax minimus*) | | | | | | | 14 | 7 | 21 | | | |
| Blue jay (*Cyanocitta cristata*) | 8 | 1 | 1 | 1 | | | 1 | | | 2 | | |
| Cowbird (*Molothrus ater*) | 92 | 4 | 4 | | | | 84 | 3 | 3 | 24 | | |
| Red-winged blackbird (*Agelaius phœniceus*) | 79 | 4 | 5 | 16 | 1 | 1 | 11 | | | 49 | 2 | 2 |
| Meadowlark (*Sturnella magna*) | 48 | 10 | 18 | 1 | | | 1 | | | 183 | 28 | 32 |
| Western meadow lark (*Sturnella neglecta*) | 52 | 8 | 11 | | | | | | | 66 | 12 | 18 |
| Orchard oriole (*Icterus spurius*) | | | | 20 | 1 | 1 | 101 | 30 | 64 | | | |
| Baltimore oriole (*Icterus galbula*) | | | | 2 | | | 50 | 11 | 24 | | | |
| Bullock oriole (*Icterus bullocki*) | | | | | | | 149 | 40 | 133 | | | |
| Rusty blackbird (*Euphagus carolinus*) | 6 | 1 | 1 | | | | | | | 10 | | |
| Brewer blackbird (*Euphagus cyanocephalus*) | 139 | 24 | 40 | 1 | | | | | | 5 | 2 | 2 |
| Bronzed grackle (*Quiscalus q. æneus*) | 36 | 5 | 5 | 19 | | | 3 | | | 3 | | |
| Great-tailed grackle (*Megaquiscalus major macrourus*) | 32 | 2 | 2 | 7 | 1 | 1 | 6 | | | 2 | | |
| Vesper sparrow (*Pooecetes gramineus*) | 29 | 1 | 1 | | | | | | | 11 | | |
| Savanna sparrow (*Passerculus sandwichensis*, subspecies) | 68 | 8 | 15 | 2 | | | | | | 18 | 1 | 1 |
| Lark sparrow (*Chondestes grammacus*) | | | | 13 | | | 54 | 1 | 1 | | | |
| White-throated sparrow (*Zonotrichia albicollis*) | 53 | 1 | 1 | 4 | | | | | | 9 | 1 | 1 |
| Field sparrow (*Spizella pusilla*) | 25 | 2 | 2 | | | | 5 | | | | | |
| Swamp sparrow (*Melospiza georgiana*) | 27 | 1 | 2 | | | | | | | | | |
| Fox sparrow (*Passerella iliaca*) | 8 | 1 | 2 | | | | | | | 9 | | |
| Towhee (*Pipilo erythrophthalmus*) | 10 | 1 | 1 | 1 | | | | | | 6 | | |
| Cardinal (*Cardinalis cardinalis*) | 42 | | | 7 | | | 39 | 3 | 4 | | | |
| Texan pyrrhuloxia (*Pyrrhuloxia s. texana*) | | | | | | | 64 | 2 | 2 | | | |
| Painted bunting (*Passerina ciris*) | | | | | | | 109 | 18 | 19 | | | |
| Dickcissel (*Spiza americana*) | | | | 1 | | | 26 | 3 | 3 | | | |
| Purple martin (*Progne subis*) | | | | 15 | 1 | 1 | 5 | 1 | 1 | | | |
| Cliff swallow (*Petrochelidon lunifrons*) | 1 | | | 1 | | | 35 | 34 | 638 | | | |
| Barn swallow (*Hirundo erythrogastra*) | | | | | | | 14 | 5 | 52 | 16 | | |
| Bank swallow (*Riparia riparia*) | | | | | | | 25 | 11 | 68 | | | |
| Loggerhead shrike (*Lanius ludovicianus*) | 46 | 1 | 4 | 4 | | | 19 | | | 12 | 2 | 5 |
| Yellow warbler (*Dendroica æstiva*) | | | | | | | 25 | 1 | 1 | | | |
| Myrtle warbler (*Dendroica coronata*) | 17 | 1 | 2 | 3 | | | | | | | | |
| Maryland yellowthroat (*Geothlypis trichas*) | 2 | 1 | 1 | 1 | | | 1 | | | | | |
| Yellow-breasted chat (*Icteria virens*) | | | | | | | 5 | 1 | 1 | | | |
| American pipit (*Anthus pensilvanicus*) | 73 | 34 | 120 | | | | | | | 8 | 3 | 4 |
| Mockingbird (*Mimus polyglottos*) | 43 | 2 | 2 | 13 | | | 85 | 5 | 5 | 5 | | |
| Brown thrasher (*Toxostoma rufum*) | 9 | | | 7 | | | | | | 29 | 1 | 1 |
| Carolina wren (*Thryothorus ludovicianus*) | 37 | 6 | 9 | 31 | 1 | 2 | 1 | | | 7 | 5 | 6 |
| Bewick wren (*Thryomanes bewicki*) | 11 | 1 | 3 | | | | 3 | | | 2 | | |
| Winter wren (*Nannus hyemalis*) | 1 | 1 | 2 | | | | | | | | | |
| Tufted titmouse (*Bæolophus bicolor*) | 14 | 5 | 7 | 23 | | | | | | | | |
| Black-crested titmouse (*Bæolophus atricristatus*) | | | | | | | 1 | | | 2 | 1 | 1 |
| Carolina chickadee (*Penthestes carolinensis*) | 6 | 1 | 1 | | | | 1 | | | 1 | | |

It will be noticed that the largest numbers of boll weevils were eaten during the months of July, August, and September, and also that a considerable number are consumed during the hibernating season. The most important birds are those that capture the boll weevil during the winter. According to this table these are the three species of blackbirds, two meadowlarks, six species of native sparrows, the pipit, the three species of wrens, and the two species of titmice. It will be noted that only one of the 108 quail stomachs examined showed remains of the boll weevil.

## REPRESSION.

### EFFECT OF BURIAL OF SQUARES AND WEEVILS.

The effect of the burial of squares and weevils is of considerable importance for the reason that some degree of burial can be practiced in the ordinary processes of cultivation. If it were to be found that the weevils could be killed by a depth of burial which could be accomplished without interference with the root system of the plants this process would be of vast importance.

At Tallulah, La., in 1910, Mr. G. D. Smith conducted an extensive series of burial experiments. The infested squares were placed in screened cages in the field. In each of these cages 2,000 infested squares were placed on October 10. A careful estimate showed that there were 250 live weevil stages for each 2,000 squares. In the first of the cages the infested squares were placed upon a sheet of wire screen 2 feet above the ground. These squares were kept constantly moist. In the second cage the squares were placed on the surface of the ground. No artificial moisture was supplied. In the third cage the squares were on the surface of the ground but were kept moist constantly. In the fourth cage the squares were buried to a depth of 2 inches and the ground was kept moist. In the fifth cage the squares were buried 4 inches and the ground was kept dry. The artificial moisture was applied three times each day during the course of the experiment. The "dry" cages were covered with canvas so that rains could not reach the squares. The soil in the locality was the typical "buckshot" of the Mississippi Delta. Immediately before the institution of the experiments several rains had made the soil moist. Observations on emergence were made from October 10 until November 15.

Table LXVII summarizes the results of these experiments.

TABLE LXVII.—*Summary of experiments in the burial of squares infested by the boll weevil at Tallulah, La., October and November, 1910.*

| | Conditions. | Emergence (weevils). | Emergence. |
|---|---|---|---|
| | | | *Per cent.* |
| Cage 1.... | 2 feet above surface, moist | 119 | 47.6 |
| Cage 2.... | On surface, dry | 157 | 62.8 |
| Cage 3.... | On surface, moist | 147 | 58.8 |
| Cage 4.... | Buried 2 inches, dry | 62 | 24.8 |
| Cage 5.... | Buried 2 inches, moist | 6 | .2 |
| Cage 6.... | Buried 4 inches, dry | 18 | .7 |
| Cage 7.... | Buried 4 inches, moist | 0 | .0 |

It will be noticed that the greatest emergence was from the two cages in which the squares were placed upon the surface of the ground. At 2 and 4 inches beneath the surface the emergence was very small. When kept dry beneath 2 inches of the soil 24 per cent of the possible emergence occurred, but at this depth when moisture was provided less than 1 per cent emerged. At a depth of 4 inches 0.7 per cent emerged in the dry cage, but none from the same depth where moisture was provided. It may be concluded from these experiments that burial beneath 2 or more inches of dry soil of the "buckshot" variety will prevent the emergence of a large portion of the weevils. If the soil is kept moist with burial at 2 inches or more below the surface the emergence is practically negligible. This is shown most clearly by comparing cages 4 and 5 in the table.

## LABORATORY EXPERIMENTS IN BURIAL.

In an experiment performed at Victoria, Tex., in 1904, 1,000 infested squares were buried under from 2 to 5 inches of well-pulverized earth.[1] Seventy-five weevils emerged. Twenty-seven weevils were found which had been unable to reach the surface. Their location varied from the bottom of the receptacle to just beneath the surface. The weighted average of the distances covered by the weevils which failed to reach the surface was 2 inches.

In another series of experiments at Victoria, Tex., 74 squares were placed under wet soil. It was found that 16 per cent of the weevil stages were killed. Of the weevils which became adult 30 per cent emerged from the squares, but only 23 per cent reached the surface or escaped from an average depth of 1 inch. In these experiments, considering all the weevil stages present, 35 per cent died without escaping from the soil.

In 1904 Prof. E. D. Sanderson performed a number of burial experiments at College Station, Tex. At from 0.5 inch to 1.5 inches below the surface 26.7 per cent of the weevils emerged; at from 2 to 4 inches 4.7 per cent reached the surface.

It will be noted that these laboratory experiments substantiate the conclusion drawn from the field experiments described previously regarding the greatly increased mortality brought about by deep burial and by moisture.

## BURIAL OF ADULT WEEVILS AT TIME OF HIBERNATION.

On or after November 23, 1903, at Victoria, Tex., 1,000 adult weevils were buried under from 2 to 6 inches of soil which contained from 9 to 19 per cent of water. Only five of these weevils succeeded in reaching the surface. Four of those which escaped and one which was still buried in the earth were found alive when examination was made on March 16, 1904. All the remaining weevils appear to have died where they were buried.

## CONCLUSIONS FROM BURIAL EXPERIMENTS.

The field and laboratory experiments to which references have been made indicate that the boll weevil has comparatively little ability to emerge from moist soil, while dry, partially pulverized soil offers small obstacles to their emergence. The experiments also show that burial, even under moist conditions, would have to be as deep as 2 inches to bring about very decided results. The practical question therefore is whether in cotton fields the soil can be turned over to a depth of 2 inches during the growing season without injury to the crop. As is well known, one of the most important cultural methods in producing cotton is shallow cultivation. The reason for this is that the plant sends many lateral roots almost at right angles from the rows and at a very short distance beneath the surface. Many of these lateral roots lie only 2 or 3 inches beneath the ground. If they were disturbed, the plants would react by shedding the squares. Undoubtedly the loss of fruit from this cause would more than offset any possible advantage accruing from the destruction of the

[1] Much more thoroughly pulverized than would be the case in the field.

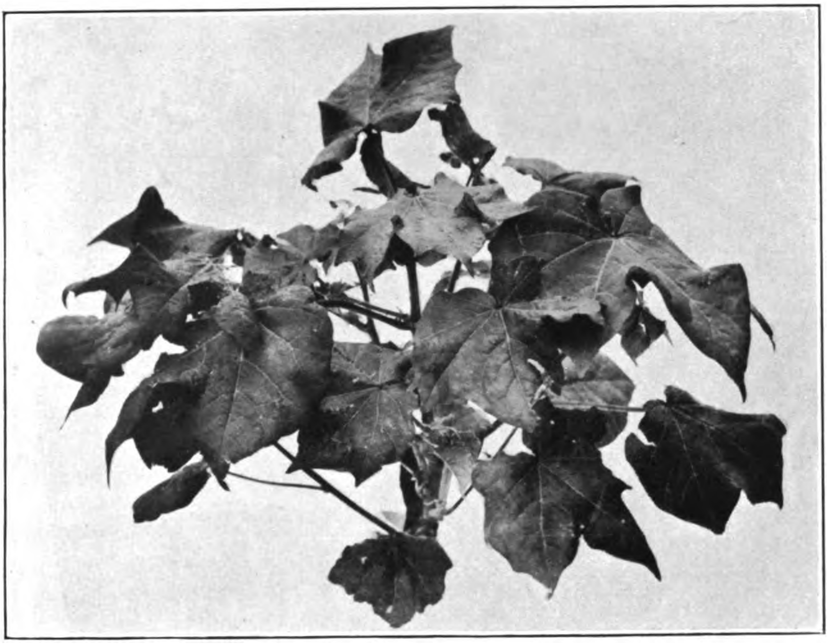


*Fig. a.*—Cotton before treatment with Paris green. (Original.)

*Fig. b.*—Cotton one week after treatment with Paris green. (Original.)

EFFECT OF PARIS GREEN ON COTTON.

weevils by burial. It is thus clear that as a means of controlling the weevil during the growing season the burial of squares is impracticable. There is a time, however, when the burial of the squares can be carried on to excellent advantage. This is in the fall when the maximum infestation has been reached. Under these conditions it makes no difference to the planter whether the lateral roots of the cotton plant are cut or not. The fruit already set on the plants will develop in either case, and any additional fruit inevitably will be destroyed by the insects. Consequently the planter may destroy many of the weevils which would mature in a short time to feed, multiply, and enter hibernation, to emerge and damage the crop of the succeeding season. In this way deep fall cultivation is a preliminary step that should be practiced in connection with the destruction of the plants. It should precede that process and should by no means be depended upon to take the place of it. After the plants have been uprooted and brought into windrows previous to burning it is advisable to plow the fields to a depth of at least 2 inches. This will result in the burial of many squares which were on the ground at the time of the uprooting or which fell during the process. The experiments show that the effectiveness of burial either before or after the uprooting of the plants will increase greatly if rains occur after the work is done. Likewise it is evident that the destruction of the weevils will be much greater in heavy soils than in lighter formations. In the Mississippi-Yazoo Delta the general nature of the soils is more or less heavy. This and the heavy precipitation in that region indicate a means of destroying the weevil that is especially important on account of the scarcity of direct means available.

## INSECTICIDES.[1]

From the very beginning of the work on the boll weevil much attention has been given to testing the more promising insecticides. As one result of the offer of a $50,000 prize by the State of Texas for an efficient remedy for the boll weevil, large numbers of supposed remedies have been proposed. Doubtless the inventors have been perfectly sincere in their faith in the efficiency of these compounds. As was fully anticipated by the entomologists when the reward was offered, the commission charged with awarding the money was deluged with applications therefor, the claims in a large majority of cases being based upon some concoction supposed by the inventor to possess marvelous insecticidal properties. In comparatively few cases had the new product been tested in any way. Often samples were sent with the request that tests be made. Many of these inventions found their way to the various laboratories of this investigation, where it has been the uniform policy to give every thing of this kind a fair test and report the results to the originator. Tests were made in the field upon weevils confined by cages. This work has required a great deal of time, and the results have failed to indicate a single new compound having real value. Many of the substances tried had absolutely no effect on either plant or insect life, while others were equally fatal to both wherever they came in contact with them. The primary difficulty with all such insecticides lies in the fact that,

[1] The first two paragraphs under this heading have been modified from Bull. 51, Bureau of Entomology, p. 156.

owing to the peculiar habits and life history of the weevil, the poison can not be so applied as to reach the immature stages at all, and it can not reach the adults so as to cause sufficient mortality to result in any considerable benefit to the crop. Much work has been done in thoroughly testing the effect of Paris green. The most important results of this work have already been published in Farmers' Bulletin No. 211 of the Department of Agriculture. They will be described briefly on a subsequent page.

Among 40 other compounds tested, none proved worthy of even passing consideration for field use. As a fumigant for seed, among the eight gases or vapors tested, carbon bisulphid was found to possess considerable value when applied in the special manner described on pages 162, 163.

## POWDERED ARSENATE OF LEAD.

In 1909 Messrs. Wilmon Newell and G. D. Smith, then of the Louisiana Crop Pest Commission, published the results of certain work with powdered arsenate of lead as a remedy against the boll weevil. This work was done in central Louisiana during the season of 1909. The principal experiments were located on three different plantations on plats provided for the purpose. From 1 to 10 applications were made, consisting of a total amount of poison of from 1 to 51 pounds per acre. The treated cotton yielded an average of 71 per cent more than similar cotton which was not treated. In all except one of the plats there was a net profit from the use of the poison (that is, after deducting the cost of the poison and of the labor from the value of the increased yield) of from 27 cents to $23.54 per acre. In the one exception there was a loss of $7.07 per acre.

These striking results led to extensive work on powdered arsenate of lead by the Bureau of Entomology. The services of Mr. G. D. Smith, who was directly connected with the Louisiana work to which reference has been made, were obtained. The bureau instituted numerous experiments in Louisiana, including several which duplicated the previous work in that State. This investigation has now extended through two seasons in Louisiana, and considerable work has also been done at Victoria, Tex., by Mr. J. D. Mitchell.

In the experiments of 1910, 32 plats were utilized on plantations at Livonia, Shaw, and St. Joseph, La., and Victoria, Tex. In the work in Louisiana there was a profit from the use of the poison on 20 of the plats and a loss on the 12 remaining plats. The average loss on the plats which failed to show a profit was $6.99 per acre. The average profit on the remaining plats was $5.83 per acre. Twenty-two of the 32 plats showed an increased yield of from 35 pounds to 403 pounds of seed cotton per acre. A striking result was the fact that invariably the plats upon which small amounts of the poison were applied showed profits. The work at Victoria, Tex., in 1910, consisted of four experiments. In only one of these experiments was a gain in yield obtained, and this amounted to only 59 pounds of seed cotton per acre. In all of the experiments at this place there was a loss from the application of the poison of from $1.55 to $6.52 per acre.

In 1911 the work on powdered arsenate of lead was continued. In some respects the results were contradictory of those obtained previously, but there was agreement in that profits were obtained on all

plats where small applications were made. On account of the apparent contradictions and the variations due to the seasons it is considered necessary to continue the work another season before definite conclusions as to the practical value of arsenate of lead can be drawn.

## MACHINES.

### FIELD MACHINERY.

Many attempts have been made to perfect machines that will assist in the warfare against the weevil. The only one of direct value that has been perfected is the chain cultivator (Pl. XX, *b;* Pl. XXI) invented by Dr. W. E. Hinds, formerly of the Bureau of Entomology, and patented by the Department of Agriculture for the benefit of the people of the United States. Its construction is based upon the discovery that the weevils in the infested squares that fall in such position as to be reached by the sun soon die. In a cotton field many of the infested squares fall within the shade of the plants, and are thus protected. The chain cultivator is designed to drag the fallen squares to the middles of the rows and leave them exposed to the sun. This it has been found to accomplish in a satisfactory manner. In fact, in tests the use of the machine has been found to result in a decided gain in production.

Although the chain cultivator was designed primarily for bringing the squares to the middles, it was found in field practice to have a most important cultural effect. The chains (so-called "log chains") are heavy enough to establish a perfect dust mulch and to destroy small weeds that may be starting. In fact, it is believed that this cultural effect would more than justify the use of the machine, regardless of the weevil. In view of the effect against the insect and the important cultural effect, it is believed that this implement or one similar to it should be used by every farmer in the weevil territory.

The chain cultivator is now regularly manufactured by one of the large dealers in farm implements, but a satisfactory machine can be made by any blacksmith. Full directions are to be found in Farmers' Bulletin 344, a copy of which may be obtained upon application to the Secretary of Agriculture.

Some forms of cultivators now in use allow the attachment of boards which drag on the ground and carry the infested squares to the middles. In fact, the principle of the chain cultivator can be incorporated in many implements now in use. It is strongly recommended that this be done for weevil control as well as for obtaining a dust mulch.

[1] Many machines have been designed to jar the weevils and infested squares from the plant and to collect them, to pick the fallen squares from the ground, to kill by fumigation, and to burn all infested material on the ground. The Bureau of Entomology has carefully investigated the merits of representatives of all of these classes, beginning in 1895 with a square-collecting machine that had attracted considerable local attention in Bee County, Tex. Up to the present time none of these devices has been found to be practical or to offer any definite hope of being eventually successful. At one

[1] The following three paragraphs are modified from Bull. 51, Bureau of Entomology, p. 157.

time there seemed some hope that a machine designed to pick the squares from the ground by suction might be perfected. The experiments, however, have indicated probably insurmountable difficulties; and a large implement concern, after having experimented with the matter fully, has come to the conclusion that mechanical difficulties will always prevent the perfection of such a machine.

The ultimate test of all methods or devices for controlling the weevil is to prove through a series of seasons, and under a large variety of conditions, that by their use there is produced an increase in the crop treated or protected of sufficient value to more than repay the expenses of the treatment or protection. As a general rule, where machines have been used or poisons applied, planters have provided no check upon the results obtained and have kept no close records as to the expense involved and net gain or loss resulting from the treatment. The result of such applications is, therefore, merely a general impression of gain or loss which may not agree at all with the facts.

In this connection it must be stated that all machines which assist in more satisfactory methods of preparation of the land and cultivation of the crop are of indirect advantage. This is especially the case with devices which increase the amount of work that a single hand or team of mules may do. In fact, the boll weevil has been the cause of much commendable improvement of agricultural machinery throughout the infested territory.

### GINNING MACHINERY.[1]

The more important results of studies upon this class of machinery were presented in Farmers' Bulletin No. 209 of the Department of Agriculture. Modern cleaner feeders were found to be quite efficient in separating the weevils from the seed cotton, as they removed fully 70 per cent of the weevils passing into them. Of the weevils removed, over 80 per cent were still alive when taken from the trash. This fact shows the necessity for the use of some additional device which will crush or otherwise destroy all weevils taken from the cotton by the cleaner feeder. (See Pl. X, *a.*)

For the weevils escaping the action of the cleaner feeder and passing into the ginning breast with the roll there are two avenues of escape—one with the seed, the other with the motes. In these two ways it appears that over 85 per cent of the weevils passing into the gin breast escape alive, while the remainder are killed by the saws. From these facts it is evident that some way should be provided for properly caring for the motes so as to confine the weevils which are thrown out among them and secure their destruction with those removed by the cleaner feeder. Some method should also be devised for separating from the seed the weevils that pass the saws before they reach the seed house or the farmers' seed bins.

When we consider the important effect that gins have been found to possess in spreading the weevil, especially near the border line of infestation, it appears exceedingly desirable that improvements in gin machinery should be made in the following particulars:

First. The area and distance through which the action of the picker roll in the cleaner feeder is continued should be considerably increased;

[1] This section is modified from Bull. 51, Bureau of Entomology, pp. 158, 159.

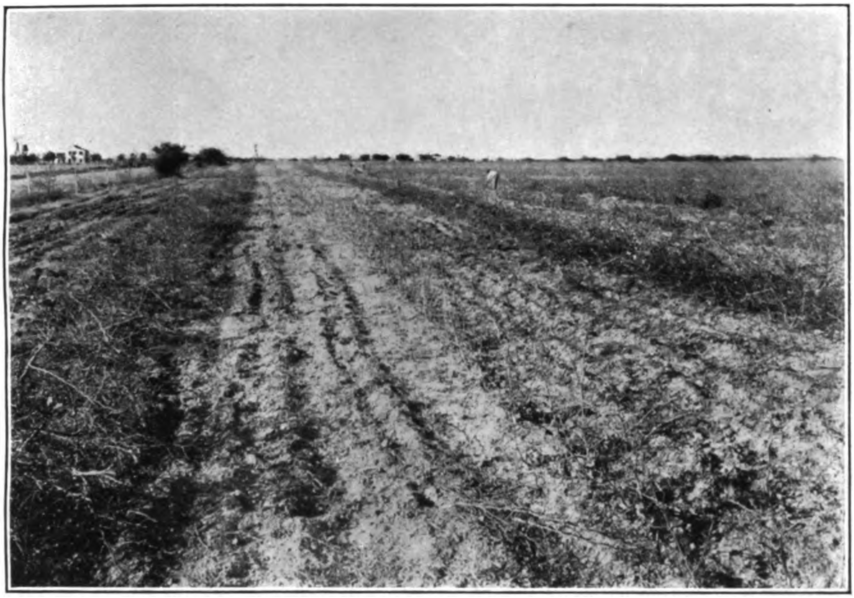


*Fig. a.*—Early fall destruction of stalks, the fundamental method for controlling the boll weevil. Windrowing stalks for burning. (Original.)

*Fig. b.*—Chain cultivator passing through cotton rows. (Original.)

CULTURAL CONTROL OF THE BOLL WEEVIL.

*Fig. a.*—Space between cotton rows before passage of cultivator. (Original.)

*Fig. b.*—Effect after passage of cultivator. (Original.)

USE OF CHAIN CULTIVATOR.

compression rollers or some other device being employed to destroy the weevils separated by the cleaner.

Second. Some method should be devised for keeping under control the weevils escaping alive with the motes, as under present conditions they have free range through the ginnery.

Third. Possibly the most important of the devices needed is an apparatus which may be applied near the gin (possibly as the seeds leave the gin breast and drop into the seed chute) by which the weevils may be separated from the seed and brought under control, so that they may be destroyed.

With these improvements the oil mills would almost cease to be a factor in the dissemination of weevils, and the movement of seed, either for planting, stock feeding, or fertilizer, would practically cease to be what it is at present, a factor in the spread of the weevil.

## FUTILE METHODS WHICH HAVE BEEN SUGGESTED.[1]

### MINERAL PAINT AND COTTONSEED OIL.

The very serious nature of the boll-weevil problem is constantly illustrated by the manner in which various useless devices and nostrums are brought to public attention. At one time it was widely alleged that mineral paint would act as a specific against the weevil. An equally fallacious theory that also received considerable popular attention was to the effect that cottonseed meal exerted a powerful attraction for the pest.

### SPRAYING.

Probably the most important useless recommendation has been that of spraying. It was supposed for some time by certain parties that it might be possible to poison weevils economically by attracting them to some sweetened preparation. The experiments conducted to determine the attraction of various sweetened substances demonstrate the fallacy of the theory. Even if these substances exerted as much attraction as was supposed, there would be insurmountable difficulties in the application of the method in the field. It is true that it is possible to destroy a certain number of weevils in regions where stubble cotton occurs by heavily spraying the earliest plants, but this method is of immeasurably less importance than the simple practice of cultural methods.

### SULPHUR.

The old idea, the fallacy of which has been explained repeatedly by economic entomologists for the past 50 years, namely, that sulphur can be forced into the system of the plants to make them immune to insect attack, sometimes crops out with reference to the boll weevil. It is scarcely necessary to call attention to the fallacy of attempting to destroy the boll weevil by soaking the seed in chemicals with the hope of making the plants that are to grow from them distasteful or poisonous to the insect. Any money expended by the farmer in following this absurd practice is entirely wasted.

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[1] This section is greatly modified from Bull. 51, Bureau of Entomology, pp. 159, 160.

### PARIS GREEN.

One of the most important fallacies regarding a remedy for the boll weevil was that which received great attention during the season of 1904, namely, that Paris green is a specific for the pest. The urgent demand for a specific was evidenced by the very extensive use of this substance. A portion of the great attention that it received publicly was due to the fact that early in the season a certain number of weevils may be killed by it. Applications made by spraying are even less effective than dusting with the dry Paris green. As was pointed out in Farmers' Bulletin No. 211, which deals with exhaustive field and laboratory experiments with Paris green, the number so destroyed in the spring really means nothing whatever to the crop later in the season when the plants have put on squares and the poison is no longer effective. As a matter of fact, the uselessness of Paris green was quickly discovered by planters. Since 1904 practically none has been used in the warfare against the pest. (See Pl. XIX.)

### TRAPPING AT LIGHT.

There is still, in many quarters in Texas and Louisiana, a supposition that it is possible to attract the boll weevil to lights. A number of machines have been constructed based upon this idea. Whether or not the boll weevil can be attracted to lights was one of the first matters that was investigated by entomologists. During September, 1897, Mr. J. D. Mitchell, of Victoria, Tex., a naturalist and cotton planter, set out trap lanterns in a cotton field in Victoria for one night, and sent the insects captured to this bureau for examination. In all, 24,492 specimens were taken, representing approximately 328 species. Divided according to habit, whether injurious or beneficial, the result was: Injurious species, 13,113 specimens; beneficial species, 8,262 specimens; of a negative character, 3,117. The interesting point in connection with this experiment was the fact that not a single specimen of the boll weevil was found, although the lights were placed in the midst of fields where the insects were very abundant. Since that time other investigators have looked into this matter fully. Lights have been kept burning in cotton fields night after night for several weeks. In no case has a single specimen of the boll weevil been discovered, although thousands of species of insects have been captured.

The popular misapprehension about the possibility of capturing the boll weevil at lights is due to the fact that somewhat similar insects, *Balaninus victoriensis*, and other acorn weevils, differ from the boll weevil in that lights exert a strong attraction for them. During occasional seasons the acorn weevils are exceedingly common in Texas, and great numbers of them fly to the electric lights.

### OTHER PROPOSED REMEDIES.

Hundreds of proposed remedies, in addition to those which have been mentioned, have been carefully investigated. The claims of their advocates in practically all cases are based upon faulty observations or careless experiments. The strong tendency of the weevil to die in confinement, which has been referred to, has caused many

honest persons to suppose that the substances they are applying have killed it. Moreover, an insuperable difficulty that these special preparations have encountered is the impracticability of the application in the field. Hundreds of known substances will kill the weevil when brought into contact with it. The difficulty is to apply them in an economical way in the field. The claims made at different times of the repellent power of tobacco, castor-bean plants, and pepper plants against the boll weevil have no foundation whatever. In fact, none of these plants has the least effect in keeping weevils away from cotton.

## REQUIREMENTS OF A SATISFACTORY METHOD OF BOLL-WEEVIL CONTROL.[1]

The difficulties in the way of controlling the boll weevil lie both in its habits and manner of work and also in the peculiar industrial conditions involved in the production of the staple in the Southern States. The facts that in all stages, except the imago, the weevil lives within the fruit of the plant, well protected from any poisons that might be applied, and in that stage takes food normally only by inserting its snout within the substance of the plant; that it frequently requires only 12 days for development from egg to adult, and the progeny of a single pair in a season may exceed 3,000,000 individuals; that it adapts itself to climatic conditions to the extent that the egg stage alone in November may occupy as much time as all the immature stages together in July or August, are factors that combine to make it one of the most difficult insects to control. It is, consequently, natural that all the investigations of the Bureau of Entomology have pointed toward the prime importance of methods of control which involve no outlay for materials and very little for labor. Methods which involve some direct financial outlay for material or machinery are not in accord with labor conditions surrounding cotton production in the United States. Moreover, the indirect methods advocated are in keeping with the general tendency of cotton culture; that is, to procure an early crop, and at the same time have the great advantage of avoiding damage by a large number of other destructive insects, especially the bollworm. Nevertheless it must not be understood that attention has not been paid to the investigation of means looking toward the direct extermination of the pest. Much work has been done, but the results have all been negative.

## BASIS FOR MEANS OF REPRESSION.

In spite of the many difficulties involved in the control of the boll weevil certain generally satisfactory means of repression are at hand. They consist of both direct and indirect means. Those of an indirect nature are designed to increase the advantage gained by the direct measures and to increase the effectiveness of the several natural factors which serve to reduce the number of weevils. Thus, the control measures constitute a combination of expedients, the parts of which interact in many ways. Naturally, the best results are obtained when the planter can put into practice all of the essential parts of the combination.

[1] This section is greatly modified from Bull. 51, Bureau of Entomology, pp. 160, 161.

It is obvious that any method of controlling the boll weevil must depend upon full knowledge regarding its life history and the natural forces which tend to prevent its multiplication. Certain practices which upon superficial observation might be considered important in the control of the insect upon investigation may be found to be of no avail whatever. In fact, in some cases what appear to be feasible means of control are worse than useless, because they tend to nullify the effects of natural forces which act against the weevil. This is notably the case with the practice of attaching a bar to a cultivator to jar the infested squares from the plants. As will be explained later, this practice is of advantage only under very restricted conditions. Throughout the greater part of the infested territory it is an assistance rather than a hindrance to the boll weevil.

There are seven features of the life history of the weevil that are of cardinal importance in control. These are indicated below.

1. The weevil has no food plant but cotton.
2. The mortality of the weevil during the winter is very high.
3. The emergence from hibernating quarters during the spring is slow and prolonged until well into the summer.
4. Early in the season, on account of comparatively low temperatures, the development of the weevil is much slower than during the summer months.
5. The drying of the infested squares, as the result of heat, soon destroys the immature stages of the weevil contained therein.
6. The weevil is attacked by many different species of insect enemies, the effectiveness of which is increased by certain practices.
7. The weevil has but little ability to emerge when buried under wet soil.

Exactly how each of these features of the life history of the weevil affects plans for practical control will be explained in the following paragraphs.

In the case of many of the important injurious insects the problem of control is greatly complicated by the fact that the pests can subsist upon more than one food plant. In some cases a single species attacks several cultivated crops. In other cases the pests can subsist upon native plants practically as well as upon the cultivated species. All these difficulties are absent in the case of the boll-weevil problem. As has been shown in the preceding pages, the insect is absolutely restricted to the cotton plant for food and for opportunities for breeding. The problem is therefore much more simple than it would be if the weevil could subsist upon any other plant in the absence of cotton. This peculiarity of the weevil was the basis of the recommendation made in 1894 that the pest be exterminated absolutely in the United States by the abandonment of cotton. At that time only a few counties in Texas were affected. The procedure would have involved small expense. Even now the weevil could be exterminated in a single season by preventing the planting of cotton and the growth of volunteer plants. This proposal has been made at various times, notably at the national boll-weevil convention held in Shreveport, La., in 1906.

Various difficulties, however, appear to render the plan entirely impracticable. In the first place, there would be strong opposition in large regions in Texas where the planters have learned to combat

the weevil successfully. This opposition would undoubtedly be sufficiently strong to prevent cooperation in a large territory. Moreover, the expense would be enormous. A large army of inspectors would be required. The work would not end with the prevention of planting cotton, but would necessarily extend to the destruction of volunteer plants which would be found along roads, railroads, about gins and oil mills, and on plantations throughout the infested region. The loss to mills, railroads, merchants, banks, and others dependent upon the cotton trade would complicate matters further. Unless a plan of reimbursement were followed there would be strenuous opposition from these quarters, and any scheme of payment for damages would increase the cost still further. From a theoretical standpoint all the expenses involved would be justified. The saving in a few years would more than offset the cost. Nevertheless, the practical difficulties undoubtedly will always prevent the execution of the plan. All interests now seem to favor the necessary adjustment of conditions to the boll weevil rather than total eradication—once practicable but now little more than visionary.

Under the discussion of the hibernation of the weevil it was shown that during the several years in which careful experiments have been performed the average rate of survival was 7.6 per cent. It is noteworthy that frequently the survival is much smaller. In the experiments to which reference has been made it ranged from 0.5 per cent to 20 per cent. The most important means of controlling the boll weevil that are available are designed to increase the tremendous mortality caused by natural conditions during the winter. The destruction of any certain number of weevils during the winter is much more important than the destruction of much larger numbers at any other season. The best means at the command of the farmer for increasing the winter mortality is through the uprooting and burning or burial of the stalks at an early date in the fall. (See Pl. XX, *a*.) Numerous experiments have shown the lessened mortality due to depriving the weevils of their food at early dates in the autumn. In fact, the experiments showed a practically uniform increase in the number of weevils surviving as the dates of the destruction of the plants became later. For instance, in all of the experiments performed in Texas it was found that destruction in September resulted in a survival of only 0.2 per cent; destruction two weeks later showed a survival of 2.3 per cent; destruction during the last half of October, 5.6 per cent; and during the first half of November, 15.4 per cent. The results of the Louisiana experiments were similar. Destruction in September showed a survival of 0.3 per cent; destruction in the first half of October, 2 per cent; in the last half of October, 8 per cent.

In addition to the experiments in which the weevils have been placed in cages at different times in the fall, the Bureau of Entomology has conducted considerable field work to show the benefits of fall destruction. The most striking experiment was performed at Calhoun County, Tex., in 1906. In this experiment an isolated area of over 400 acres of cotton was utilized. There was no other cotton within a distance of 15 miles. By contracts entered into by the department, the farmers uprooted and burned all of the stalks during the first 10 days in October, and provision was made to prevent

the growing of sprout cotton. As a check against this area, cotton lands about 30 miles away were used. Here the stalks were not destroyed in the fall, and the interpretation of the results of the experiment was based upon a comparison of the number of weevils present during the following season in the two localities. In May following the destruction of the plants careful search revealed only one weevil in the experimental area. In the check, however, the weevils were so numerous at this time that practically all of the squares had been destroyed. Examinations made later showed similar advantage in regard to freedom from the boll weevil of the area where the stalks were destroyed in October. The last examination was made on August 20. At this time there were 10 sound bolls to the plant on the experimental area and only 3 to the plant in the check area. The difference in yield between the two areas was about 600 pounds of seed cotton per acre. The work, therefore, resulted in an advantage amounting to about $18 per acre.

Newell and Dougherty[1] have described a very satisfactory device for cutting the cotton stalks in the fall. It consists of a triangular wooden framework, designed to pass between the rows and cut two at the same time. In the process of cutting, the machine windrows the stalks from two rows into the middle between the rows. The runners are provided with knives made of sharpened metal. Old saws have been found well adapted to the purpose. It is important to provide a metal runner at the rear end of the machine to prevent sliding. This runner is designed to run an inch or more beneath the surface of the ground. The device can be made by any blacksmith at a cost of about $4. It will cut and windrow from 10 to 15 acres of stalks in a day.

There is a disadvantage in cutting the stalks at or near the surface of the ground: If warm weather follows, many of the roots will give rise to sprouts that will furnish the weevils food. On this account the process is less effective than uprooting the plants. Wherever the stalk cutter is used, it should be followed by plows to remove the roots from the ground.

There is another important means by which the winter mortality of the weevil may be increased. This is by removing the hibernating quarters or destroying them after the weevil has gone into hibernation. Many of the insects are to be found in the winter in trash and débris found in and about cotton fields. The more shelter there is provided in the form of weeds growing about the fields, the more favorable the conditions will be for the insect. By the burning of such hibernating quarters as are found in the cotton fields and in their immediate vicinity a farmer can cut off a very large proportion of the weevils that would otherwise emerge to damage the crop.

The prolonged period of emergence from hibernation gives the planter another important advantage over the weevil. It has been shown on preceding pages that the period of emergence from hibernation extends, in normal seasons, to practically the 1st of July. In fact, except in one of the experiments that was performed, the last weevils did not appear until after the 20th of June. In the one exception the last weevils appeared on the 6th of June. In Texas it was found that 75 per cent of the emerging weevils appeared after

[1] Cir. 30, Louisiana Crop Pest Commission.

April 8 and in Louisiana 64 per cent. In Texas, after May 1, in all the experiments, from 4 to 18 per cent of the surviving weevils appeared. In Louisiana, after May 1, from 30 to 40 per cent emerged.

It is obvious that the fact that many weevils do not appear until long after cotton can be planted and brought to a fruiting stage is a very great advantage to the planter. A portion of a crop at least can be set before the weevils have become active. Usually it is possible to plant a crop sufficiently early to have it set some fruit before much more than 50 per cent of the surviving weevils have emerged.

Attention was directed to the fact that the development of the weevil is much slower in the early portion of the season than later. For instance, at Vicksburg, Miss., the average period of development in April is 30 days and in May 19 days. In June the period is shortened to 15 days. Consequently the planter has an opportunity to force the development of fruit on the plants when the weevils are being held in check by the temperatures of the spring months. The ability of the cotton plant to grow during April and May is much greater than that of the weevils. This gives a margin of which the planter can take advantage.

In the section dealing with natural control it was shown that climatic checks are the most important that the boll weevil experiences. The principal manner in which climatic factors affect the weevil is through the drying of the fruit. Naturally, the more heat and light there is to reach the fallen squares, the greater will be the effectiveness of the most important natural means of control. This is the basis for the recommendation that the plants should be given considerable space, not only between the rows, but in the drill. Of course, it would be possible to place the plants entirely too far apart, and thus reduce the yield. There is a happy medium, however, at which planters must arrive from experience on their individual places. At the same time, varieties should be cultivated which have a minimum tendency toward the formation of leafage.

The work of the insect enemies of the boll weevil is increasing from year to year. This work should be encouraged in so far as possible. It happens that several of the recommendations made for other reasons will result in facilitating the work of the enemies of the weevil. This is the case with early planting, wide spacing, and the use of varieties with sparse rather than dense leafage. Even fall destruction is not a disadvantage, because it forces the parasites at the active season to native hosts that carry them through the winter. Wherever possible, varieties should be planted which retain a large proportion of the infested squares, because the hanging squares are more favorable for parasite attack than those which fall.

Whenever the squares are picked by hand they should not be burned or buried, but placed in screened cages. In this way the weevils will be destroyed while the parasites may escape.

Numerous experiments have shown that a large proportion of the weevils buried under 2 inches of moist soil can not reach the surface. Unfortunately, it is not possible to plow the infested squares under 2 inches of soil during the growing season. The operation would result in injury to the root system and cause great shedding. Nevertheless it is possible for the planter to follow this practice after maximum infestation has been reached and after the plants have

been uprooted. Therefore, every means should be taken at the time of maximum infestation to plow under the infested squares as deeply as possible. This method is of little use in dry regions, but fortunately is of great importance in humid regions where other means of control are comparatively lacking in efficiency. It is also assisted greatly by the occurrence of large areas of so-called stiff soils in the humid area.

## SUMMARY OF MEANS OF REPRESSION OF THE BOLL WEEVIL.

In the preceding pages all effective methods of controlling the boll weevil have been described in a general way, and their connection with the life history of the insect shown. Further details regarding the application of the methods have been published in Farmers' Bulletin 344. In the present connection it will be sufficient to summarize the subject. The following are the essential features of the control of the boll weevil:

1. *Prevention of the invasion of new territory by means of quarantines directed against farm commodities that are likely to carry the weevil.* It is not necessary to have a quarantine applied to an extended list of articles. Only a few forms of cotton and of cotton by-products need to be considered. The most important is seed cotton. Next in importance are cottonseed and cottonseed hulls. There is no danger in cottonseed meal and scarcely any appreciable danger in baled cotton.

Cottonseed can be easily rendered entirely safe by fumigation with carbon bisulphid, as described in this bulletin.

2. *The destruction of the weevils in the fall by uprooting and burning or burying the plants.* This is by far the most important step in control. (See Pl. XX, *a*.) It is so important that unless it is followed all other means will avail little to the planter.

The burning of the cotton plants is, of course, a bad agricultural practice. It should not be followed except in extreme emergencies. In all other cases the plants should be uprooted as soon as the cotton can be picked and cut by means of stalk choppers and immediately plowed beneath the surface. The ground should afterwards be harrowed or dragged to make it still more difficult for the insects to emerge.

In many cases it will be found inadvisable to wait for the uprooting of the plants until all of the cotton is picked. After only a small portion remains for the pickers, it is entirely feasible to uproot the plants by means of a turning plow and leave them in the field so that the cotton can be picked. This will hasten the opening of the green bolls and frequently result in a considerable saving to the planter.

3. *The destruction of the weevils during the winter.* This is accomplished by the destruction of the places in which the insects hibernate. Many such places are found in the cotton fields or in their immediate vicinity. A certain number of the weevils will of course make their way into the heavy woods and other situations beyond the reach of of the planter, but many remain where they can be reached.

4. *Obtaining an early crop.* (See Pl. XXII.) The importance of obtaining an early crop has been shown to depend upon the small number of weevils which hibernate successfully, their late emergence from hibernating quarters, and their comparatively slow development

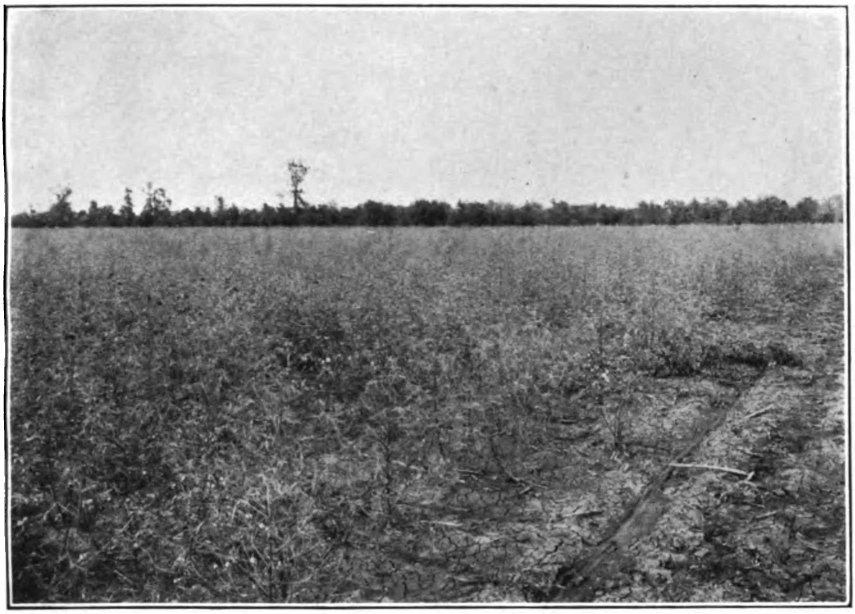

*Fig. a.*—Late-planted cotton under boll-weevil conditions, given same culture as early planting. (Original.)

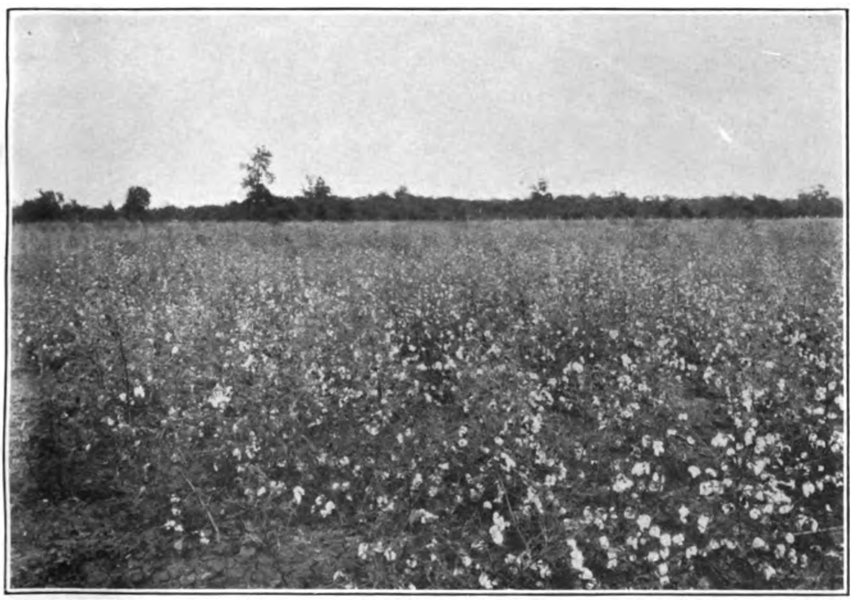

*Fig. b.*—Early-planted cotton adjoining the late planting under same conditions. (Original.)

RESULTS OF EARLY AND LATE PLANTING OF COTTON.

during the early part of the season. The obtaining of an early crop is brought about by early preparation of the soil, by early planting, by the use of early-maturing varieties, by a system of fertilization which will stimulate the growth of the plants, and by continuous shallow cultivation during the season.

5. *Increasing the effects of climatic control.* As has been shown, practically 50 per cent of all the weevil stages throughout the infested territory are destroyed by climatic influences. This means that the power of reproduction of the weevils is reduced by one-half. A planter can increase the advantage in his favor by providing a suitable distance between the plants and between the rows. It is also important to use varieties, where possible, which have a comparatively small leaf area. The use of the chain cultivator will be found of great value in connection with obtaining the full effects of climatic control.

6. *Encouraging the insect enemies of the weevil.* This is accomplished in part by procedures already recommended and further by the use of varieties which have a well-developed tendency to retain the fruit and which also have a comparatively open structure and small leafage.

7. *Hand picking of weevils and squares.* This is a practice of little general importance. Although under some local conditions it may be highly advisable, everything depends upon the cheapness with which the work can be done. On crops produced by wage hands it is doubtful if the hand picking of the weevils or squares will ever result in any profit. Where the crop is produced on the share basis, and the acreage is sufficiently small to allow considerable work in the picking of the squares, the practice will undoubtedly pay. It is, therefore, a matter that must be taken into consideration by each individual planter. It can not be recommended generally, for the reason that under many conditions it would result in loss.

Wherever square picking is practiced the squares should not be burned. They should be placed in cages, so that the parasites may escape and continue their work. As a matter of fact, under most conditions it is likely that the encouragement that can be given the parasites by this means is of much more importance than any direct checking of the weevil by the process of hand picking. Wherever squares are burned the planter is merely destroying the enemies of the weevil and consequently working against his own interest.

8. *Control at gins.*—The use of modern cleaner feeders will eliminate practically all of the weevils from cottonseed. Such devices should be used at least in the case of all seed that is intended for shipment into any infested localities and especially along the outer border of the infested territory, where wagons may carry infested cottonseed some distance into territory that has not been reached by the weevil. It is important in connection with the cleaner feeders to provide some means for the destruction of the insects that are captured. In some cases where the cleaner feeders are in operation the discharge is allowed to accumulate in an open barrel or box. From such receptacles weevils readily make their way into the seed cotton in storage. It is a simple matter to provide compression rollers through which the discharge from the cleaner feeder is passed. If, for any reason, the use of compression rollers is impracticable, the trash should be

fumigated at frequent intervals by means of carbon bisulphid or collected in a closed chamber and burned before the weevils have an opportunity to escape. (See Pl. X, *a*.)

9. *Fumigation of seed* (fig. 34). This is a means of repression that will be of avail only in the case of shipments of seed into uninfested territory. It has been found that carbon bisulphid is the most satisfactory agent to use. Great care should be taken to insure thoroughness of application.

The use of a crossbar attached to the cultivator to jar the infested squares from the plants has frequently been recommended. Under some conditions this practice should be followed, but under others it is worse than futile. It was shown, in the treatment of the subject of natural control of the weevil, that in the humid region, including Arkansas, Louisiana, and the eastern portion of Texas, the mortality in hanging squares is greater than in fallen squares. For this reason it is better for the squares to remain on the plants. There is another reason why they should be allowed to remain on the plants which applies especially to the moist region in which the boll weevil is now doing great damage. This is, that the hanging squares are much preferred by the boll-weevil parasites. The records have invariably shown a higher rate of parasitism in hanging squares than in fallen squares. In this way the hanging squares furnish a means for the breeding of parasites, thereby enabling them to establish themselves in the field.

It will be noted that the means of repression of the boll weevil may be divided into two classes, namely, direct and indirect.

The direct means of control are the destruction of the weevils in the fall by destroying the plants and burning or burying the immature stages, hand picking of weevils and squares under some conditions, the burial of the infested forms at the time of maximum infestation, and the burning of the hibernating weevils in their winter quarters.

The indirect means of control are early planting, the use of early varieties and of fertilizers that will accelerate growth, the selection of fields where the soil is suitable to rapid development, frequent shallow cultivation, the encouragement of the parasites of the weevil by placing the infested squares that may be picked by hand in cages instead of burning them, and the use of machinery which facilitates the various operations in preparing the land and cultivating the crop. These have the effect of increasing the acreage that a hand may cultivate. In view of the fact that the boll weevil forces a reduction in the acreage per hand, this is a consideration of some moment.

## DESTROYING THE BOLL WEEVIL IN COTTON SEED.

It has been shown in this bulletin that adult weevils are frequently to be found in cotton seed and that there is danger in the dissemination of the pest through the shipment of the seed. A number of experiments have been performed to discover means of killing the weevils found in seed. There are great difficulties to be overcome on account of the density of the seed and its practical impenetrability by certain fumigants. It was shown, for instance, that hydrocyanic-acid gas has practically no penetrating power whatever. Carbon bisulphid was found to be satisfactory, although a special apparatus and special manipulation of the seed are necessary to insure

success. The method described below, from Farmers' Bulletin 209, is that which has been used by the bureau in cases where it has been necessary to free cotton seed of the weevils.

The following plan for this work is proposed: A tight matched-board box should be provided having sides 4 feet high, open on top, and of other dimensions to accommodate 12 or more 100-pound sacks of cotton seed placed upright upon the bottom. Another tier of sacks could be added if desired. Into each one of these sacks about 1 ounce of carbon bisulphid should be forced by an apparatus for volatilizing the liquid and mixing the vapor with air. The accompanying illustration (fig. 34) will give an idea of this apparatus. It should consist of three essential parts, as shown in the illustration. *A* is an air pump having sufficient storage capacity to enable it to maintain a steady discharge of air for several minutes without continuous pumping. The stopcock at $a_1$ regulates or prevents the escape of air, as may be desired. *B* is an ordinary 2-quart bottle fitted at $b^1$ with a tight stopper of good length, having two openings, through which the inlet and outlet pipes pass. These pipes may be of glass or metal and should be as large as can be used. The inlet pipe, $b_2$, reaches nearly to the bottom of the bottle and is provided at the lower end with a perforated metal cap as large as will pass through the neck of the bottle. This allows the escape of the air in small bubbles and insures rapid evaporation. The outlet pipe, $b_4$, reaches only through the stopper. Upon the outside of the bottle is pasted a paper marked with 1-ounce graduations. *C* is a piece of ordinary ⅜-inch iron gas pipe about 3½ feet long, but this may be any desired length. It is closed and roundly pointed at the tip, and for about 15 to 18 inches of its length provided with small perforations pointing in all directions to give free escape to the vapor into all parts of the sack of seed at once.

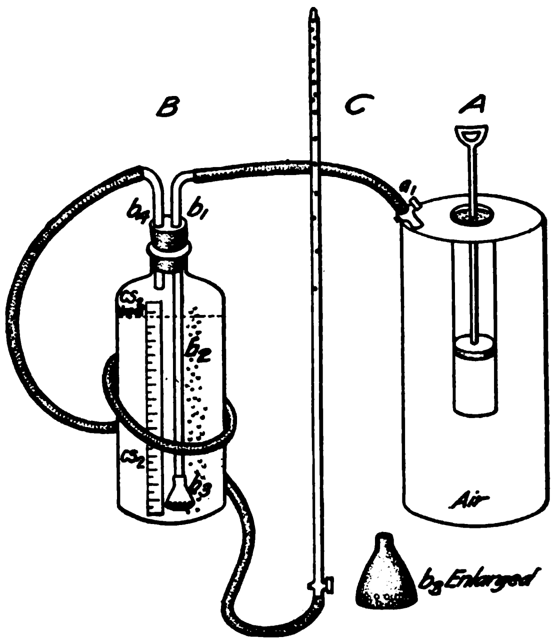

FIG. 34.—Apparatus for fumigating cotton seed in the sack. (After Hunter.)

The connections may be of rubber tubing, but as little rubber as possible should be used for this apparatus, as it is affected by the vapor of the bisulphid, and the couplings will have to be frequently replaced. This, however, will not be a considerable item of expense. With the apparatus just described one operator would be able to accomplish the entire work of disinfection. The amount of carbon bisulphid recommended is about 1 ounce for each 3-bushel sack. It is safe to say that this can be secured for less than 1 cent per ounce when purchased in 25 or 50 pound lots, making the cost of bisulphid not over 1 cent per sack. As it requires but from two to three minutes to vaporize 1 ounce of the liquid in the manner described, the expense for labor in application would not amount to one-half a cent per sack. Fumigation with carbon bisulphid can therefore be effectively made at the slight expense of from 1 to 1½ cents per 100-pound sack.

Application of the bisulphid in this manner reduces the elements of danger to a minimum, as the vapor is almost wholly confined and the slight quantity escaping, mixed with the open air, would not be in either inflammable or explosive proportions. It has been determined that the slight trace of bisulphid vapor in the air would not injure the operator in the slightest degree. The sacks should be left in the box for forty hours after the gas is injected.

## LEGAL RESTRICTIONS REGARDING THE BOLL WEEVIL.

### UNITED STATES STATUTE.

The statute, quoted in part below, prohibits the interstate shipment of the boll weevil and certain other insects, and provides penalties:

AN ACT To prohibit the importation or interstate transportation of insect pests, and the use of the United States mails for that purpose.

That no railroad, steamboat, express, stage, or other transportation company shall knowingly transport from one State or Territory into any other State or Territory, or from the District of Columbia into a State or Territory, or from a State or Territory into the District of Columbia, or from a foreign country into the United States, the * * * boll weevil, in a live state, or other insect in a live state which is notoriously injurious to cultivated crops; * * * or the eggs, pupæ or larvæ of any insect injurious as aforesaid, except when shipped for scientific purposes under the regulations hereinafter provided for, nor shall any person remove from one State or Territory into another State or Territory, or from a foreign country into the United States, or from a State or Territory into the District of Columbia, or from the District of Columbia into any State or Territory, except for scientific purposes under the regulations hereinafter provided for, the * * * boll weevil, * * * in a live state, or other insect in a live state which is notoriously injurious to cultivated crops; * * * or the eggs, pupæ or larvæ of any insect injurious as aforesaid. (33 Stat. L., 1269.)

SEC. 2. That any letter, parcel, box, or other package containing the * * * boll weevil * * * in a live state or other insect in a live state which is notoriously injurious to cultivated crops; * * * or any letter, parcel, box, or package which contains the eggs, pupæ or larvæ of any insect injurious as aforesaid, whether sealed as first class matter or not, is hereby declared to be nonmailable matter, except when mailed for scientific purposes under the regulations hereinafter provided for, and shall not be conveyed in the mails, nor delivered from any post office, nor by any letter carrier, except when mailed for scientific purposes under the regulations hereinafter provided for; and any person who shall knowingly deposit, or cause to be deposited, for mailing or delivery, anything declared by this section to be nonmailable matter, or cause to be taken from the mails for the purpose of retaining, circulating, or disposing of, or of aiding in the retention, circulation or disposition of the same shall, for each and every offense, be fined, upon conviction thereof, not more than five thousand dollars or imprisoned at hard labor not more than five years, or both, at the discretion of the court: *Provided*, That nothing in this Act shall authorize any person to open any letter or sealed matter of the first class not addressed to himself. (33 Stat. L., 1270.)

SEC. 3. That it shall be the duty of the Secretary of Agriculture and he is hereby authorized and directed to prepare and promulgate rules and regulations under which the insects covered by sections one and two of this Act may be mailed, shipped, transported, delivered and removed, for scientific purposes, from one State or Territory into another State or Territory, or from the District of Columbia into a State or Territory, or from a State or Territory into the District of Columbia, and any insects covered by sections one and two of this Act may be so mailed, shipped, transported, delivered and removed, for scientific purposes, under the rules and regulations of the Secretary of Agriculture: *Provided*, That the rules and regulations of the Secretary of Agriculture, in so far as they affect the method of mailing insects, shall be approved by the Postmaster-General, and nothing in this Act shall be construed to prevent any State from making and enforcing laws in furtherance of the purposes of this Act, prohibiting or regulating the admission into that State of insects from a foreign country. (33 Stat. L., 1270.)

SEC. 4. That any person, company, or corporation who shall knowingly violate the provisions of section one of this Act shall, for each offense, be fined, upon conviction thereof, not more than five thousand dollars or imprisoned at hard labor not more than five years, or both, at the discretion of the court. (33 Stat. L., 1270.)

### QUARANTINES OF THE SEVERAL STATES.

Quarantines designed to prevent the importation of the boll weevil are now in force in the following States and Territories: Alabama, California, Georgia, Louisiana, Mississippi, North Carolina, Okla-

homa, Porto Rico, South Carolina, Tennessee, and Texas. They are directed against all infested counties and States, as well as against all counties which may become infested in the future. The following pages give the substance of the present restrictions. For further particulars the quarantine officers of the several States should be addressed directly.

*Alabama.*—The present quarantine regulations in Alabama were promulgated by the Alabama State board of horticulture on April 4, 1911. The quarantine applies to cotton seed, seed cotton, hulls, seed-cotton and cottonseed sacks (which had been used), cotton-pickers' sacks, and corn in the shuck. Importation of these articles into uninfested territory from infested territory, or from any point situated within 20 miles of the area known to be infested, is prohibited. However, between January 15 and July 15 shipments of these articles originating within or ginned within a zone 20 miles in length immediately adjoining the infested territory may be made to points not more than 40 miles outside of the line of infestation. Between October 1 and June 30 shipments of Spanish moss, baled or unbaled, originating in infested territory, are prohibited from entering or passing through uninfested parts of the State. Cotton lint (loose, baled, flat, or compressed) originating in infested localities is prohibited except during the months of June, July, and August. The shipment of household goods is prohibited unless accompanied by an affidavit attached to the waybill to the effect that the shipment contains no cotton, cotton seed, seed cotton, hulls, seed-cotton and cottonseed sacks, cotton-pickers' sacks, corn in the shuck, or loose Spanish moss, except that in shipments of household goods made during the months of July, August, and September corn shucks or Spanish moss may be used for packing. All shipments of quarantined articles must be made in tightly closed box cars. No person except the entomologist of the State board of horticulture and his deputies is allowed to have in possession outside of the weevil-infested territory any live stages of the boll weevil. The penalty provided is a fine of from $100 to $500.

*California.*—In California the boll-weevil quarantine is in the form of an order issued by the State commissioner of agriculture on April 23, 1908. This provides that all cotton seed shipped into California shall be consigned through one of the State deputy commissioners of horticulture. These shipments shall be fumigated with carbon bisulphid for a period of 24 hours by a deputy commissioner. Deputy commissioners are located at El Centro, San Bernardino, Riverside, Los Angeles, and San Diego.

*Florida.*—The restrictions in effect are authorized by a statute passed in 1911 which established the office of inspector of nursery stock. Dr. E. W. Berger, Gainesville, is the present inspector.

*Georgia.*—Previous to August 15, 1904, the Georgia State board of entomology had authority, by virtue of the legislative act which created it, to enact such regulations as it deemed necessary to prevent the introduction or dissemination of injurious crop pests or diseases. On August 28, 1903, this board adopted a regulation prohibiting the introduction of cotton seed from Texas except under a certificate from an authorized State or Government entomologist stating that the seed had been fumigated in such manner as to kill any stage of boll weevils which might be contained therein. On

August 15, 1904, an act of the General Assembly of the State of Georgia was approved, but further amended August 23, 1905, whereby cotton seed, seed cotton, cottonseed hulls, or cotton lint in bales or loose, corn in the husk, or all material, including household goods packed in any of the above quarantined products, are prohibited from being brought into the State except when there is attached thereto a certificate signed by an authorized State or Government entomologist to the effect that said material was grown in and was shipped from a point where, by actual inspection, the Mexican cotton-boll weevil was not found to exist. Through shipments of quarantined articles may be made in cars which must be tightly closed, and no unloading is allowed during transit through the State. No common carrier shall use for bedding or feed for live stock any of the quarantined articles when the shipments originate in regions infested with the boll weevil.

Mr. E. L. Worsham, capitol, Atlanta, is the present quarantine official in Georgia.

*Louisiana.*—The State entomologist of Louisiana is, by a law passed December 15, 1903, empowered to quarantine against the cotton-boll weevil whenever it seems advisable. At present the State is entirely infested, but if in the future portions of the State should be freed the entomologist is fully empowered to restrict dangerous shipments into such portions.

Mr. J. B. Garrett, Baton Rouge, La., is the quarantine officer of this State.

*Mississippi.*—The State legislature in 1908 passed a law giving the entomologist of the experiment station considerable authority in regard to the quarantines against the boll weevil. As only part of the State is infested, and it may be possible to save certain portions several years of injury, the rules established in 1904 should be considered in force as restricting shipments into uninfested counties. An absolute quarantine is established against cotton seed, seed cotton, hulls, seed-cotton and cottonseed sacks (which have been used), cotton-pickers' sacks, corn in the shuck, unsacked corn, unsacked oats, unsacked wheat, and unsacked cowpeas from the infested territory. Through shipments of quarantined articles must be in tightly closed cars, which must not be unloaded while in transit through the State. Household goods to be shipped from infested territory into uninfested parts of the State of Mississippi must be accompanied by an affidavit to the effect that no quarantined articles are contained as packing or otherwise in the shipment. Baled cotton can be shipped into the uninfested parts of the State only in tightly closed cars.

Prof. R. W. Harned, Agricultural College, Miss., is the quarantine officer of this State.

*North Carolina.*—By virtue of authority from the State legislature to prevent the importation of crop pests, the North Carolina Crop Pest Commission early in 1904 adopted rules establishing a quarantine against all localities where the Mexican cotton-boll weevil is known to exist. The quarantine was absolute and applied to cotton, cotton seed, cottonseed meal, cottonseed hulls, hay, oats, corn, rice, straw, rice chaff, and other grain or material likely to harbor any stage of the boll weevil.

The rules published in July, 1910, are reproduced verbatim:

REGULATION No. 15. No transportation company, common carrier, or agent thereof, shall bring into North Carolina any shipment of seed cotton or cotton-seed hulls originating at any point in the States of Texas, Louisiana, Mississippi, Oklahoma and Alabama. And this shall likewise apply to other States when the boll weevil shall be determined to be established within their borders.

REGULATION No. 16. Shipments of cotton destined to any points in North Carolina and which originate at any point within the States of Texas, Louisiana, Mississippi, Oklahoma, Arkansas and Alabama, or other States that may hereafter become infested with cotton boll weevil, shall only be in hard compressed bales. If shipped in any other form, it is declared to be a public nuisance and is liable to seizure by the Board of Agriculture or its agents.

REGULATION No. 17. Any shipment of cotton seed which originates at any point in Texas, Louisiana, Mississippi, Oklahoma, Arkansas or Alabama, and which is destined to any point in North Carolina, can be accepted for transportation only if it shall have attached to the bill of lading a certificate or statement signed by a duly authorized State or Government Entomologist stating that the point from which said shipment originates is a locality not known to be in the area of the boll weevil infection.

REGULATION No. 18. If any shipment of seed cotton, cotton-seed hulls, cotton, or cotton seed not in accordance with these regulations be presented to any transportation company, common carrier, or agent thereof, for shipment to or delivery at any point within this State, same shall be refused, and the case shall be reported to the North Carolina State Department of Agriculture, at Raleigh, giving the name and address of the consignor and of the consignee.

Prof. Franklin Sherman, jr., Raleigh, N. C., is the quarantine officer in this State.

*Oklahoma.*—By virtue of rules and regulations issued by the State entomologist in accordance with the laws of the State, shipments of cotton seed, cottonseed hulls, seed-cotton and cottonseed sacks, cotton-pickers' sacks, and corn in the shuck are prohibited from infested territory into uninfested territory. In the same manner household goods are prohibited unless accompanied by a certificate that no quarantined material is contained therein. Through shipments of quarantined articles shall be made in tightly closed box cars and shall not be unloaded while in transit through the State. Shipments of baled cotton into uninfested parts shall be made in tightly closed box cars. No common carrier shall use for bedding or feed for live stock any of the quarantined articles which may have originated in infested territory. All persons are expressly forbidden to send live weevils in any stage to any point in or outside of the State, either by mail, express, or otherwise.

Prof. C. E. Sanborn, Stillwater, Okla., is the quarantine agent for this State.

*Porto Rico.*—By legislative act no cotton seed, seed cotton, cotton lint, loose or in bales, shall be brought into the island of Porto Rico, from any State or county whatsoever without being accompanied by the certificate of a duly authorized State or Federal entomologist that the shipment originated in a locality where, by actual inspection of such official or his agent, the boll weevil was not found to exist. Shipments not so certified are liable to seizure and destruction. Punishment is provided for in section 16 of the Penal Code of Porto Rico of 1902.

The governor of the island has direct control over the enforcement of this law.

*South Carolina.*—In South Carolina the quarantine regulations are entirely embodied in the laws of the State, and consequently not so readily modified to conform with the changed conditions and a better understanding of the methods of dissemination of the boll weevil as

is the case when authority to promulgate rules and regulations is invested in a commission or in the State entomologist. The law established to guard against the introduction of the Mexican boll weevil into the State of South Carolina was approved on February 25. 1904. The commodities quarantined against were cotton seed, oats, and prairie hay, shipped directly or indirectly from infested points in the State of Texas.

Prof. A. F. Conradi, Clemson College, S. C., can furnish information concerning the interpretation of the State law.

*Tennessee.*—In compliance with the requirements of an act of the General Assembly of the State of Tennessee (S. B. No. 442, chap. 466), approved April 17, 1905, entitled "An act to create a State entomologist and plant pathologist," etc., the State board of entomology, established by said act, announced the following rules and regulations under date of December 31, 1910.

(*a*) No cotton lint (loose, baled, flat, or compressed), cotton seed, seed cotton, cotton-seed hulls, seed-cotton or cotton-seed sacks (which have been used), or corn in the shuck, shall be shipped into Tennessee from the infested territory of Texas, Oklahoma, Louisiana, Arkansas and Mississippi.

(*b*) Shipments of household goods from infested areas of above named States shall not be admitted into Tennessee unless accompanied by an affidavit attached to the way-bill to the effect that the shipment contains no cotton lint, cotton seed, seed cotton, cotton-seed hulls, seed-cotton or cotton-seed sacks, or corn in the shuck.

(*c*) It shall be unlawful for anyone in Tennessee to have in his possession live Mexican cotton boll weevils. The public is urged to recognize the danger of introducing unwittingly live boll weevils for inspection, observation, or experiment.

Mr. G. M. Bentley, Knoxville, Tenn., is the officer in this State.

*Texas.*—In accordance with an act of the State legislature, to prevent the spread and dissemination of injurious insects, the commissioner of agriculture designated the boll weevil as such an insect to be quarantined. This ruling in the act makes it illegal to ship seed cotton or cotton seed, or any other article which might carry the boll weevil from an infested county to an uninfested county.

Mr. Ed. R. Kone, Austin, Tex., is the State officer charged with quarantine enforcement.

*Regulations of foreign governments.*—The Governments of Egypt, Peru, and India have established an injunction against the importation of American cotton seed originating in the infested localities. In all cases, however, it can be arranged to have shipments cleared in case they are accompanied by certificates of fumigation by a competent authority.

## BIBLIOGRAPHY.

This bibliography includes only the more important writings which have been published in permanent form. In the preliminary part of this bibliography a special synopsis is given of the contents of publications, more particularly to outline the history of the cultural method now recognized as of supreme importance in the control of the boll weevil. No attempt is made to give a synopsis of the later titles. For a complete annotated bibliography see Circular No. 140, Bureau of Entomology.

1843. BOHEMAN, C. H.—Genera et species Curculionidum cum synonymia hujus familiæ ed. C. J. Schönherr, vol. 5, pt. 2, pp. 232–233.

The original description of *Anthonomus grandis*.

1871. SUFFRIAN, E.—Verzeichniss der von Dr. Gundlach auf der Insel Cuba gesammelten Rüsselkäfer.<Archiv f. Naturg., vol. 37, Jahrg. 13, pt. 1, pp. 130–131.

Contains the record of a specimen from Cardenas and one from San Cristobal, in Cuba.

1885. RILEY, C. V.—Report of the Commissioner of Agriculture for 1885, p. 279.

Contains the sentence "Another very large species, *A. grandis* Boh., we have reared at this department from dwarfed cotton bolls sent from northern Mexico by Dr. Edward Palmer." This is the first published record of the food plant and method of injury of the species.

1891. DIETZ, W. G.—Revision of the genera and species of Anthonomini inhabiting North America.<Trans. Amer. Ent. Soc., vol. 18, p. 205.

The species is here reported from Texas. It has been shown, however, that this was an error. (See Insect Life, vol. 7, p. 273.)

1891. GUNDLACH, JUAN.—Contribucion á la entomologia Cubana, vol. 3, pt. 5, p. 285.

Mentions occurrence in Cuba.

1894. HOWARD, L. O.—A new cotton insect in Texas.<Ins. Life, vol. 7, p. 273.

The first authentic account of the occurrence of the species in the United States, and some statements regarding its life history.

1895. HOWARD, L. O.—The new cotton-boll weevil.<Ins. Life, vol. 7, p. 281.

1895. TOWNSEND, C. H. T.—Report on the Mexican cotton boll weevil in Texas (*Anthonomus grandis* Boh.).<Ins. Life, vol. 7, no. 4, pp. 295–309, figs. 30, 31, March.

An important preliminary paper giving valuable data on life history and habits, an account of its spread from Mexico to Texas, and its extent in Texas at that time. In the consideration of remedies are suggested the cutting and burning over of the cotton fields in winter, the abandonment of cotton growing over the region then infested, and the maintenance of a wide zone free from cotton along the lower Rio Grande bordering Mexico, with other suggestions of less practical value.

1895. HOWARD, L. O.—The Mexican cotton-boll weevil.<Cir. 6 (second series), Div. Ent., U. S. Dept. Agr., pp. 5, figs. 1–3, April.

This circular gives the results, substantially, of Mr. Townsend's field investigations of the insect in Mexico and Texas. The impracticability of the use of poisons is shown, and the collection and destruction of infested bolls and rotation of crops are suggested. English and Spanish editions were issued.

1895. RIOS, J. R.—Aparicion del "picudo" en la Laguna.<El Progreso de Mex., Aug. 15, 1895. Reprinted in vol. 4, pp. 811–813, 1897.

1896. HOWARD, L. O.—The Mexican cotton-boll weevil.<Cir 14 (second series), Div. Ent., U. S. Dept. Agr., pp. 8, figs. 1–5.

Contains a large amount of additional information relative to distribution, natural history and habits, and natural enemies and parasites, now worked out with substantial accuracy. Under the head of remedies is the first suggestion of the great importance of the cultural method of control, and especially the early fall destruction of the cotton plants, together with the recommendation of early planting and clean cultivation. Trapping late beetles in fall and over-wintered beetles in early spring is advised, together with the destruction of volunteer plants, the region infested up to this time being fairly within the range of volunteer or seppa cotton.

1897. Howard, L. O.—The Mexican cotton-boll wevil.<Cir. 18 (second series), Div. Ent., U. S. Dept. Agr., pp. 8, figs. 1–5.

This circular brings the data on distribution and other features down to date, and in the matter of remedies incorporates the results of field studies in Texas by Mr. C. L. Marlatt on food habits and poisoning, and indicates the supreme importance of the cultural method of control, all other steps being merely palliative or to offset the failure to adopt this method. Issued in English, Spanish, and German editions.

1897. Junta de defensa contra el "picudo." (Editorial.)<El Progreso de Mex., vol. 5, pp. 8–9, Oct. 8.

1897. El picudo (*Anthonomus grandis* Boh.). (Editorial.)<Documentos referentes a su existencia en Mexico y a su invasion in los Estados Unidos del Norte. Mexico Oficina Tip. de la Secretaria de Fomento, pp. 100, figs. 1–5.

1897. Balestrier, L. de.—Las medias precautorias contra las plagas que asolan a la agricultura.<El Progreso de Mex., vol. 4, pp. 575–576, May 22.

1897. Howard, L. O.—The Mexican cotton-boll weevil in 1897. Cir. 27 (second series), Div. Ent., U. S. Dept. Agr., pp. 7.

This circular records more particularly the further spread of the weevil, and repeats the suggestions relative to the cultural method of control from Circular 18, which method is urged as a practically complete remedy for the insect.

1897. Howard, L. O.—Insects affecting the cotton plant.<Farm. Bull. 47, U. S. Dept. Agr., pp. 16–23, figs. 7–11.

Reprinted from Bulletin 33, Office of Experiment Stations, U. S. Dept. Agr., pp. 317–350.

1898. Howard, L. O.—Remedial work against the Mexican cotton-boll weevil.<Cir. 33 (second series), Div. Ent., U. S. Dept. Agr., pp. 6.

This is a supplementary circular giving the results of some experiments with poisons by Mr. Marlatt and Mr. Townsend. The cultural system of control is, however, again insisted upon.

1901. Rangel, A. F.—Estudios preliminares acerca del picudo del algodon (*Insanthonomus grandis* I. C. Cu.).<Boletin de la Comision de Parasitologia Agricola, vol. 1, no. 3, pp. 93–104, pl. 9 and figure.

Deals with 45 experiments regarding destruction by means of hot air, hot water, steam, haplaphyton, and arsenic.

1901. Mally, F. W.—A preliminary report of progress of an investigation concerning the life history, habits, injuries, and methods for destroying the Mexican cotton-boll weevil (*Anthonomous* (sic) *grandis*). Authorized by special Act of the Twenty-sixth Legislature of Texas, pp. 1–30, supplement pp. 35–45.

1901. Mally, F. W.—The Mexican cotton-boll weevil.<Farm. Bull. 130, U. S. Dept. Agr., pp. 30, figs. 1–4.

A reprint, with minor corrections, of the preceding, excepting the supplement. Contains much new valuable information, but in the subject of remedies represents Mr. Mally's own point of view and not the advice of the bureau current at the same time. Nevertheless, the cultural method is again given the greatest prominence.

1901. Rangel, A. F.—Segundo informe acerca del picudo del algodon (*Insanthonomus grandis* I. C. Cu.).<Boletin de la Comision de Parasitologia Agricola, vol. 1, no. 5, pp. 171–176.

1901. Rangel, A. F.—Tercer informe acerca del picudo del algodon.<Boletin de la Comision de Parasitologia Agricola, Mexico, vol. 1, no. 6, pp. 197–206.

1901. Rangel, A. F.—Cuarto informe acerca del picudo del algodon (*Insanthonomus grandis* I. C. Cu.).<Boletin de la Comision de Parasitologia Agricola, vol. 1, no. 7, pp. 245–261, pls. 16, 23.

1901. Rangel, A. F.—Quinto informe acerca del picudo del algodon.<Boletin de la Comision de Parasitologia Agricola, Mexico, vol. 1, no. 8, pp. 302–317.

1902. Ashmead, W. H.—A new Bruchophagus from Mexico.<Psyche, vol. 9, p. 324, March.

Contains the description of *Bruchophagus herreræ* n. sp., a parasite of *Anthonomus grandis*, from Coahuila, Mexico.

1902. Rangel, A. F.—Sexto informe acerca del picudo del algodon.<Boletin de la Comision de Parasitologia Agricola, Mexico, vol. 1, no. 9, pp. 403–407.

1902. Hunter, W. D.—The present status of the Mexican cotton boll weevil in the United States.<Yearbook U. S. Dept. Agr. for 1901, pp. 369–380, 1 fig.

In this publication the cultural method of control is substantially the only method recommended, augmented by the suggestion of securing northern seed and early maturing varieties to hasten the crop production; also suggests the wide spacing of rows to secure the same end.

1902. Mally, F. W.—Report on the boll weevil. Pp. 70, figs. 3. Austin, State Printer.

1902. MADERO, J. M. C.—Una plaga del algodon.<Boletin de Agricultura. (Salvador) vol. 2, no. 14, pp. 483–485, July 15.

Comments on failure of means of control as then recommended by the United States Department of Agriculture. States that cotton growing has been abandoned on account of the weevil in Coahuila, for corn and wheat.

1903. HUNTER, W. D.—Methods of controlling the boll weevil (advice based on the work of 1902).<Farm. Bul. 163, U. S. Dept. Agr., pp. 16, figs. 2, January.

The recommendations as to the steps of the cultural method are repeated in this publication, with the added suggestion of thorough cultivation and thinning of plants in the rows as well as wide spacing to hasten maturity.

1903. BARREDA, L. DE LA.—El picudo en San Pedro de la Colonia.<Boletin de la Comision de Parasitologia Agricola, Mexico, vol. 2, no. 2, pp. 45–58.

1903. SANDERSON, E. D.—The Mexican boll weevil.<Cir. 1, Ent. Dept., Tex. Agr. Exp. Sta., no. 1. Press Notes, vol. 5, no. 3, pp. 8, figs. 4, February.

1903. Kill the boll weevil. How to grow cotton in the weevil district. History of the pest, its habits, and the remedies plainly disclosed. Pp. 8, figs. 4. Published by the Executive Committee of the Texas Boll Weevil Convention.

1903. CHAMPION, G. C.—Biologia Centrali-Americana. Coleoptera, vol. 4, pt. 4, p. 186, pl. 11, figs. 3, 3a, April.

1903. Save the cotton crop. Testimony of cotton growers on boll weevil. How to insure the cotton crop in the weevil district. Pp. 16. Published by the Executive Committee of the Texas Boll Weevil Convention, Bul. No. 2, May. Also published in German under the title, "Rettet die Baumwolle," and in Bohemian under the title, "Zachrañte bavlnu."

1903. SANDERSON, E. D.—How to combat the Mexican cotton-boll weevil in summer and fall.<Cir. 4, Ent. Dept., Tex. Agr. Exp. Sta. Press Notes, vol. 5, no. 1, pp. 4, August 10.

1903. Improved cotton seed for Texas planting. Published by the Executive Committee of the Texas Boll Weevil Convention, pp. 32. Bul. No. 4, November 9; revised November 17.

1903. MORGAN, H. A.—The Mexican cotton boll weevil. Cir. 1, La. Agr. Exp. Sta., pp. 10, figs. 3, map 1, November.

1903. WILSON, JAMES.—Report of the Secretary of Agriculture, 1903. Pp. 102–106 under heading, "Crisis in cotton production," deals with the boll-weevil problem, December.

1903. CONNELL, J. H.—Proceedings of the second annual session Texas cotton growers' convention, Dallas, Tex. Pp. 99; many illustrations, December.

1903. Proceedings of the boll weevil convention called by Governor W. W. Heard in New Orleans, La., November 30 and December 1. Issued by Louisiana Bureau of Agriculture and Immigration.

1904. SCHWARZ, E. A.—The cotton boll weevil in Cuba.<Proc. Ent. Soc. Wash., vol. 6, pp. 13–17, January 15.

Report upon investigations regarding the abundance of this species; food plants and parasites in Cuba.

1904. HERRICK, G. W.—The Mexican cotton boll weevil.<Cir. 17, Miss. Agr. Exp. Sta., pp. 7, figs. 2, February.

1904. HUNTER, W. D.—Information concerning the Mexican cotton boll weevil. <Farm. Bul. No. 189, U. S. Dept. Agr., pp. 1–31, figs. 1–8, February.

1904. SANDERSON, E. D.—The cotton boll weevil in Texas.<Cir. 8, Ent. Dept., Tex. Agr. Exp. Sta., pp. 14, figs. 6, April 15.

1904. HUNTER, W. D.—The status of the Mexican cotton boll weevil in the United States in 1903.<Yearbook U. S. Dept. Agr. for 1903, pp. 205–214, pls. 17, 18, 19, 20, 21, figs. 10, map 1.

1904. HUNTER, W. D., and HINDS, W. E.—The Mexican cotton boll weevil.<Bul. 45, Div. Ent., U. S. Dept. Agr., pp. 1–116, pls. 1–16, figs. 1–6, May 19.

1904. COOK, O. F.—An enemy of the cotton boll weevil.<U. S. Dept. Agr., Rept. 78, office of the Secy., pp. 7. Issued May 27.

1904. MORGAN, H. A.—The Mexican cotton boll weevil.<Cir. 1, State Crop Pest Comm., La., pp. 16, figs. 3, June 1.

1904. COOK, O. F.—Report on the habits of the kelep, or Guatemalan cotton boll weevil ant.<Bul. 49, Bur. Ent., U. S. Dept. Agr., pp. 15, July 26.

1904. WILCOX, E. M.—The Mexican cotton boll weevil.<Bul. 129, Ala. Agr. Exp. Sta., pp. 91–104, figs. 1–4, August.

1904. HUNTER, W. D.—Controlling the boll weevil in cotton seed and at ginneries. <Farm. Bul. 209, U. S. Dept. Agr., pp. 31, fig. 1, September 16.

1904. SANDERSON, E. D.—Insects mistaken for the Mexican cotton boll weevil.<Bul. 74, Tex. Agr. Exp. Sta., pp. 12, figs. 13, September.

1904. NEWELL, WILMON.—The Mexican cotton boll weevil.<Bul. 12, Ga. St. Bd. Ent., pp. 29, figs. 21, September.

1904. HUNTER, W. D.—The most important step in the cultural system of controlling the boll weevil.<Cir. 56, Bur. Ent., U. S. Dept. Agr., pp. 6, October 10.

1904. HUNTER, W. D.—The use of Paris green in controlling the cotton boll weevil. <Farm. Bul. 211, U. S. Dept. Agr., pp. 23, December 5.

1904. Proceedings of the second annual meeting Louisiana boll weevil convention, held at Shreveport, La., November 3 and 4, 1904. Issued by the State Board of Agriculture and Immigration.

1905. SHERMAN, FRANKLIN, Jr.—The cotton boll weevil.<Ent. Cir. 14, N. C. Dept. Agr., pp. 11, figs. 5, January 20.

1905. HUNTER, W. D.—The control of the boll weevil, including results of recent investigations.<Farm. Bul. 216, U. S. Dept. Agr., pp. 32, figs. 1–5, March.

1905. HUNTER, W. D.—Present status of the cotton boll weevil in the United States. <Yearbook U. S. Dept. Agr. for 1904, pp. 191–204, 2 pls., 1 fig.

1905. HUNTER, W. D. and HINDS, W. E.—The Mexican cotton boll weevil. A revision and amplification of Bulletin 45 to include the most important observations made in 1904.<Bul. 51, Bur. Ent., U. S. Dept. Agr., 181 pp., 23 pls., 8 figs.

1905. COOK, O. F.—The social organization and breeding habits of the cotton-protecting kelep of Guatemala.<Tech. Ser. 10, Bur. Ent., U. S. Dept. Agr., 55 pp.

1905. REDDING, R. J.—Essential steps in securing an early crop of cotton.<Farm. Bul. 217, U. S. Dept. Agr.

1905. BAILEY, VERNON.—Birds known to eat the boll weevil.<Bul. 22, Bur. Biol. Surv., U. S. Dept. Agr., 16 pp.

1905. SANDERSON, E. D.—Some observations on the cotton boll weevil.<Bul. 52, Bur. Ent., U. S. Dept. Agr., pp. 29–42, 1 fig.

1905. NEWELL, WILMON.—The remedy for the boll weevil.<Cir. 3, State Crop Pest Commission of Louisiana, 20 pp., 5 figs., November. Revised edition: 1906, March, 23 pp., 5 figs.

1906. COOK, O. F.—Weevil-resisting adaptations of the cotton plant.<Bul. 88, Bur. Plant Ind., U. S. Dept. Agr., 87 pp., 10 pls., January 13.

1906. NEWELL, WILMON.—The work of the State crop pest commission with the boll weevil.<Cir. 5, State Crop Pest Commission of Louisiana, 20 pp., 3 figs., January.

1906. CHAMPION, G. C.—Biologia Centrali Americana. Coleoptera, vol. 4, pt. 4, p. 722, April.

Boll weevil recorded from San Jose, Costa Rica.

1906. NEWELL, WILMON.—The boll weevil. Information concerning its life history and habits.<Cir. 9, State Crop Pest Commission of Louisiana, 29 pp., 15 figs., July.

1906. HOWELL, A. H.—Birds that eat the cotton boll weevil. A report of progress. <Bul. 25, Bur. Biol. Surv., U. S. Dept. Agr., 22 pp.

1906. COOK, MEL. T.—Insectos y enfermedades del algodon.<Primer informe anual de la Estacion Central Agronomica de Cuba, pp. 178–180, 1 fig.

1906. BARREDA L. DE LA.—Anotaciones al "Boletin de los agricultores," númber 216, de la Secretaria de Agricultura de los Estados Unidos.<Cir. 32, Comision de Parasitologia Agricola, Mex., pp. 42–48.

1906. HINDS, W. E.—Proliferation as a factor in the natural control of the Mexican cotton boll weevil.<Bul. 59, Bur. Ent., U. S. Dept. Agr., 45 pp., 6 pls., 11 tables, August 27.

1906. SANDERSON, E. D.—National control of introduced insect pests.<Bul. 60, Bur. Ent., U. S. Dept. Agr., p. 99, September 22.

1906. HINDS, W. E.—Laboratory methods in the cotton boll weevil investigations. <Bul. 60, Bur. Ent., U. S. Dept. Agr., pp. 111–119, 2 pls., September 22.

1906. HOWARD, L. O., and BURGESS, A. F.—The laws in force against injurious insects and foul brood in the United States.<Bul. 61, Bur. Ent., U. S. Dept. Agr., pp. 9, 34–35, 38–39, 55–60, 79–80, 108–109, 117–119, 128, 134, 139–141, 145, November 5.

All State laws against the boll weevil in force at the time of publication are given in full.

1907. SANDERSON, E. D.—Hibernation and development of the cotton boll weevil. <Bul. 63, Bur. Ent., U. S. Dept. Agr., pt. 1, 38 pp., 6 figs., January 15.

1907. FLYNN, C. W., JR.—The boll weevil.<Cir. 11, State Crop Pest Commission of Louisiana, 19 pp., 2 figs., January.

Report on the cultural experiments in cooperation with the Bureau of Entomology during 1906.

1907. HINDS, W. E.—An ant enemy of the cotton boll weevil.<Bul. 63, Bur. Ent., U. S. Dept. Agr., pt. 3, pp. 45–48, 1 fig., February 5.

1907. MORGAN, A. C.—A predatory bug reported as an enemy of the cotton boll weevil. Papers on the cotton boll weevil and related and associated insects. <Bul. 63, Bur. Ent., U. S. Dept. Agr., pt. 4, pp. 49–54, figs. 8–9, February 8.

Life history and habits of a bug, *Apiomerus spissipes* Say, reported as an enemy of the boll weevil.

1907. HUNTER, W. D.—Some recent studies of the Mexican cotton boll weevil. <Yearbook, U. S. Dept. Agr., for 1906, pp. 313–324, 1 pl., 1 map.

1907. FLYNN, C. W., JR.—Experiments in the late planting of cotton to avoid boll weevil damage, during 1906.<Bul. 92, La. Agr. Exp. Sta., 8 pp., May.

1907. CRAWFORD, J. C.—New hymenopterous parasites of *Anthonomus grandis* Boh.<Can. Ent., vol. 39, pp. 133–134, April.

Original description of *Torymus anthonomi*, *Urosigalphus anthonomi*, and *Urosigalphus schwarzi*, all reared from the boll weevil.

1907. NEWELL, WILMON.—Report upon the work of the State Crop Pest Commission <Cir. 13, State Crop Pest Commission of Louisiana, pp. 4–5, April.

1907. NEWELL, WILMON.—Fighting the boll weevil by picking up the infested squares.<Cir. 15, State Crop Pest Commission of Louisiana, 4 pp., June.

1907. MAYER, AUGUST.—The most important factor in solving the boll weevil problem.<Cir. 16, State Crop Pest Commission of Louisiana, 8 pp., June 20.

Discussion of the relation of the cattle tick to the boll weevil problem. Particular stress is placed upon the necessity of eradicating the cattle tick so as to enable the cotton growers of the South to raise cattle profitably and thus have the manure to increase the productivity of the soil.

1907. NEWELL, WILMON.—The State Crop Pest Law of Louisiana and rules and regulations of the State Crop Pest Commission, in effect July 1, 1907.<Cir. 17, State Crop Pest Commission of Louisiana, 19 pp., July.

1907. PIERCE, W. D.—On the biologies of the Rhynchophora of North America. <Ann. Rept. Nebr. St. Bd. Agr., pp. 269, 295–307, 1 pl.

1907. HERRICK, G. W.—The boll weevil.<Cir. Miss. Agr. Exp. Sta., 7 pp., 1 fig., September.

1907. HUNTER, W. D.—The most important step in the control of the boll weevil. <Cir. 95, Bur. Ent., U. S. Dept. Agr., 8 pp., October 13.

1907. HUNTER, W. D., NEWELL, WILMON, and PIERCE, W. D.—The insect enemies of the cotton boll weevil.<Cir. 20, State Crop Pest Commission of Louisiana, 7 pp., 3 figs., December.

1907. HINDS, W. E.—Some factors in the natural control of the Mexican cotton boll weevil.<Bul. 74, Bur. Ent., U. S. Dept. Agr., 79 pp., 4 pls., 2 figs., 17 tables, December 14.

1907. HOWELL, A. H.—The relation of birds to the cotton boll weevil.<Bul. 29, Bur. Biol. Surv., U. S. Dept. Agr., 31 pp., 1 pl., 6 figs.

1907. BARREDA, L. DE LA.—Las plagas del algodonero.<Boletin de la Comision de Parasitologia Agricola, Mex., vol. 4, no. 2, pp. 107–215, 24 pls., 1 map.

1907. HENSHAW, H. W.—Birds useful in the war against the cotton boll weevil. <Cir. 57, Bur. Biol. Surv., U. S. Dept. Agr., 4 pp.

1908. PIERCE, W. D.—Studies of parasites of the cotton boll weevil.<Bul. 73, Bur. Ent., U. S. Dept. Agr., 63 pp., 3 pls., 6 figs., January 21.

1908. BENNETT, R. L.—A method of breeding early cotton to escape boll weevil damage.<Farm. Bul. 314, U. S. Dept. Agr., pp. 30, figs. 1–16, February 17.

1908. SHERMAN, FRANKLIN, JR.—Erroneous reports of cotton boll weevil—its present status.<Ent. Cir. 21, N. Car. Dept Agr., 4 pp., March.

1908. NEWELL, WILMON.—The boll weevil.<Second Bien. Rept. Sec. State Crop Pest Commission of Louisiana for the years 1906-1907, pp. 9–16; also an appendix.

1908. KNAPP, S. A.—Demonstration work in cooperation with southern farmers. <Farm. Bul. 319, U. S. Dept. Agr., 22 pp., April 6.

1908. NEWELL, WILMON, and PAULSEN, T. C.—The possibility of reducing boll weevil damage by autumn spraying of cotton fields to destroy the foliage and squares.<Journ. Econ. Ent., vol. 1, pp. 113–117, April 15.

1908. PIERCE, W. D.—The economic bearing of recent studies of the parasites of the cotton boll weevil.<Journ. Econ. Ent., vol. 1, pp. 117–122, April 15.

1908. Crawford, J. C.—Some new Chalcidoidea.<Proc. Ent. Soc. Wash., vol. 9, pp. 157–160, April 25.

Original descriptions of *Cerambycobius cushmani* and *Catolaccus hunteri*, reared from the cotton boll weevil.

1908. Newell, Wilmon, and Rosenfeld, A. H.—A brief summary of the more important injurious insects of Louisiana.<Journ. Econ. Ent., vol. 1, p. 151, April 15.

1908. Newell, Wilmon.—The early cotton and the boll weevil.<Cir. 22, State Crop Pest Commission of Louisiana, 7 pp., May.

1908. Howell, A. H.—Destruction of the cotton boll weevil by birds in winter. <Cir. 64, Bur. Biol. Surv., U. S. Dept. Agr., 5 pp., 1 map, June 19.

1908. Newell, Wilmon, and Barber, T. C.—Preliminary report upon experiments with powdered arsenate of lead as a boll weevil poison.<Cir. 23, State Crop Pest Commission of Louisiana, pp. 9–40, 3 figs., July.

1908. Hinds, W. E.—The first and last essential step in combating the boll weevil. <Journ. Econ. Ent., vol. 1, no. 4, pp. 233–243, August 15.

1908. Newell, Wilmon, and Trehearne, R. C.—A new predaceous enemy of the boll weevil.<Journ. Econ. Ent., vol. 1, p. 244, August 15.

Note of the destruction of adult boll weevils by the carabid beetle, *Evarthrus sodalis* Le C., as also by another species of Evarthrus.

1908. Newell, Wilmon.—Destroying the boll weevils before they enter hibernation. <Cir. 24, State Crop Pest Commission of Louisiana, pp. 41–48, August.

1908. Pierce, W. D.—Factors controlling parasitism with special reference to the cotton boll weevil.<Journ. Econ. Ent., vol. 1, pp. 315–323, October 15.

1908. Pierce, W. D.—A list of parasites known to attack American Rhynchophora. <Journ. Econ. Ent., vol. 1, pp. 380–396, December 15.

1908. Hutchinson, W. L.—Cotton culture in Mississippi in areas infested with the Mexican cotton boll weevil.<Bul. 117, Miss. Agr. Exp. Sta., 6 pp., December.

1908. Hunter, W. D.—The cotton boll weevil in Oklahoma.<First Bien. Rept., Okla. St. Bd. Agr. to the Legislature of the State, for the years 1907–08, part 5, pp. 36–42.

1909. Hunter, W. D.—What can be done in destroying the cotton boll weevil during the winter.<Cir. 107, Bur. Ent., U. S. Dept. Agr., 4 pp., January 12.

1909. Hunter, W. D.—The boll weevil problem with special reference to means of reducing damage.<Farm. Bul. 344, U. S. Dept. Agr., 46 pp., 9 figs., January 23.

1909. Bennett, R. L.—Growing cotton under boll weevil conditions.<Bul., Miss. Agr. and Mech. Coll., Farm. Inst. Dept., vol. 6, no. 1, 13 pp., January.

1909. Newell, Wilmon.—What constitutes a perfect stand of cotton when fighting the boll weevil?<Special Boll Weevil Bul. 1, La. St. Bd. Agr. and Immig. Cir. 25, State Crop Pest Commission of Louisiana, 15 pp.

1909. Newell, Wilmon, and Rosenfeld, A. H.—Report upon variety and fertilizer experiments with cotton in the boll weevil infested sections of Louisiana. <Cir. 26, State Crop Pest Commission of Louisiana, pp. 65–86, February.

1909. Hinds, W. E.—Facing the boll weevil problem in Alabama.<Bul. 146, Ala. Agr. Exp. Sta., pp. 81–102, 2 pls., 1 fig., June.

1909. Newell, Wilmon, and Dougherty, M. S.—The "V" cotton-stalk cutter. How to make it and how to use it.<Cir. 30, State Crop Pest Commission of Louisiana, pp. 151–158, 4 figs., September 15.

1909. Newell, Wilmon, and Dougherty, M. S.—The hibernation of the boll weevil in central Louisiana.<Cir. 31, State Crop Pest Commission of Louisiana, pp. 163–219, 6 figs., October.

1909. Hinds, W. E., and Yothers, W. W.—Hibernation of the Mexican cotton boll weevil.<Bul. 77, Bur. Ent., U. S. Dept. Agr., 106 pp., 10 pls., 9 figs., October 18.

1909. Newell, Wilmon, and Smith, G. D.—Experiments with powdered arsenate of lead as a practical boll weevil poison.<Cir. 33, State Crop Pest Commission of Louisiana, pp. 251–333, 4 figs.

1910. Hunter, W. D.—The status of the boll weevil in 1909.<Cir. 122, Bur. Ent. U. S. Dept. Agr., 12 pp., 1 fig.

1910. Harned, R. W.—Boll weevil in Mississippi, 1909.<Bul. 139, Miss. Agr. Exp. Sta., 43 pp., 28 figs., March.

1910. Pierce, W. D.—On some phases of parasitism displayed by insect enemies of weevils.<Journ. Econ. Ent., vol. 3, no. 6, pp. 451–458, December 15.

1911. BISHOPP, F. C.—An annotated bibliography of the cotton boll weevil.<Cir. 140, Bur. Ent. U. S. Dept. Agr., June 14.

1911. PIERCE, W. D.—Some factors influencing the development of the boll weevil. <Proc. Ent. Soc. Wash., vol. 13, pp. 111-117, June 19.

1911. ROSENFELD, A. H.—Insects and spiders in Spanish moss.<Journ. Econ. Ent., vol. 4, no. 4, pp. 398-409.

1911. CUSHMAN, R. A.—Studies in the biology of the boll weevil in the Mississippi Delta region of Louisiana.<Journ. Econ. Ent., vol. 4, no. 5, pp. 432-448, October 16.

1912. HUNTER, W. D.—The movement of the Mexican cotton boll weevil in 1911. <Cir. 146, Bur. Ent., U. S. Dept. Agr., 4 pp., 1 fig. (map), February 12.

1912. PIERCE, W. D.—Systematic notes and descriptions of some weevils of economic or biological importance.<Proc. U. S. Nat. Mus., vol. 42, no. 1889, pp. 155-170.

1912. PIERCE, W. D., CUSHMAN, R. A., and HOOD, C. E.—The insect enemies of the cotton boll weevil.<Bul. 100, Bur. Ent. U. S. Dept. Agr., pp. 99, pls. 3, figs. 26, March 15.

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